INSTRUCTION MANUAL

Type 1617 CAPACITANCE BRIDGE

GENERAL RADIO COMPANY

C

INSTRUCTION MANUAL

Type 1617 CAPACITANCE BRIDGE

Form 1617-0100-C
ID 2485
April, 1968

NOTE: This instrument is equipped with our new snap-on knob for added convenience and safety. Refer to the Service Section for details.

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West Concord, Massachusetts, USA

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

SPECIFICATIONS

Quantity	*Frequency*	*Range*	*Accuracy*
Capacitance	120 Hz internal *	0 to 0.11 F	± 1% ± 1 pF, smallest division 2 pF; residual ("zero") capacitance approximately 4 pF
		0.11 F to 1.1 F	± 2%
	40 Hz to 120 Hz external (useful down to 20 Hz with reduced accuracy)	0 to 1.1 F	Same as above with suitable generator
	120 Hz to 1000 Hz external	0 to 1 F $\left(\frac{100}{f_{Hz}}\right)^2$	± 1% ± 1 pF with suitable generator and precautions
Dissipation Factor	120 Hz internal or 40 Hz to 120 Hz	0 to 10 $\frac{f_{Hz}}{120}$*	± 0.001 ±0.01 C (in F) ± 2%
	120 Hz to 1 kHz	0 to 10	$\left(\pm 0.001 \pm 0.01\ C\ (\text{in F})\right) \frac{f_{Hz}}{120} \pm 2\%$*

Lead-Resistance Error (4-terminal connection): Additional capacitance error of less than 1% and *D* error of 0.01 for a resistance of 1Ω in each lead on all but the highest range, or 0.1Ω on the highest range.

Internal Test Signal: 120 Hz (synchronized to line) for 60-Hz model; 100 Hz for 50-Hz model. Selectable amplitude less than 0.2 V, 0.5 V, or 2 V. Phase reversible.

External Test Signal: 20 Hz to 1 kHz with limited range (see above).

Internal DC Bias Voltage and Voltmeter: 0 to 600 V in 6 ranges.

Voltmeter Accuracy: ± 3% of full scale.

Internal DC Bias Current: Approximately 15 mA maximum.

Ammeter Range: 0 to 20 mA in 6 ranges. Can detect ½-μA leakage.

Ammeter Accuracy: ± 3% of full scale.

External Bias: 800 V maximum.

Power Required: 105 V to 125 V or 210 V to 250 V, 60 Hz, 18 W maximum. Models available for 50-Hz operation.

Accessories Supplied: Four-lead and shielded two-lead cable assemblies.

Accessories Required: None for 120-Hz measurements. The Type 1311 Oscillator is recommended for measurement at spot frequencies, the Type 1310 Oscillator for continuous frequency coverage.

Mechanical Data: Flip-Tilt Case.

	Width		*Height*		*Depth*		*Net Wt*		*Ship Wt*	
Model	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	16¼	415	15	385	9	230	26	12	34†	15.5
Rack	19	485	14	355	6⅛**	160	28	13	43†	20

*120 Hz is the frequency of the internal signal for the 60-Hz model; it becomes 100 Hz in the 50-Hz model.

**Behind panel. †Estimated.

Summary of EIA and MIL Specifications on Testing Electrolytic Capacitors

Specification and Capacitor Type	*Frequency*	*AC Level*	*Accuracy* C	*Accuracy* *Loss*	*DC Polarizing Voltage*
MIL C—3965 C Tantalum Foil and Sintered Slug Capacitors	120±5 Hz	Less than 30% of DCWV or 1 V, whichever is smaller	2%	*R* or P.F. 2%	C—Sufficient for no reversal of polarity. *D*—"Polarized Capacitance Bridge" Sum of ac and dc shall not exceed DCWV.
MIL C—26655-B Solid Tantalum Capacitors	120±5 Hz	Limited to 1V, rms	2%	*D*, 10%	C—Max bias 2.2 V. *D*—"Polarized Bridge", 2.2-V dc max.
RS 228 Tantalum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	*D*, 5%	Optional
MIL C-62 B Polarized Aluminum Capacitors	120±5 Hz	Limited to 30% of DCWV or 4 V, whichever is smaller	2%	*D*, 2%	No bias required if ac voltage less than 1 V. However, if bias causes differences, measurements with bias shall govern.
RS 154 B Dry Aluminum Electrolytic Capacitors	120 Hz	Small enough not to change value	±2½%	*R* or RC	Optional; but if substantial difference occurs, rated dc should be used.
RS 205 Electrolytic Capacitors for use in Electronic Instruments	120 Hz	Small enough not to change value	±2½%	*D*	Optional

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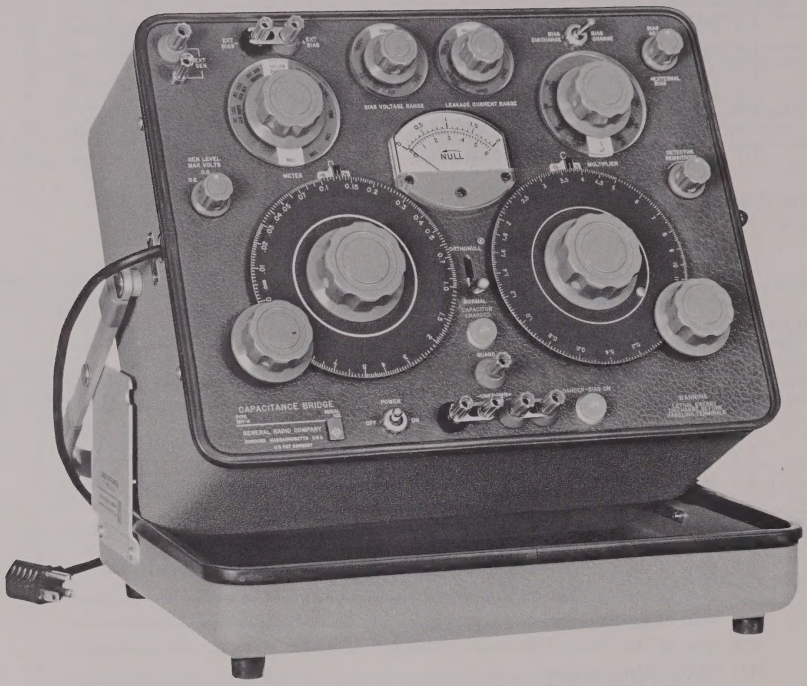
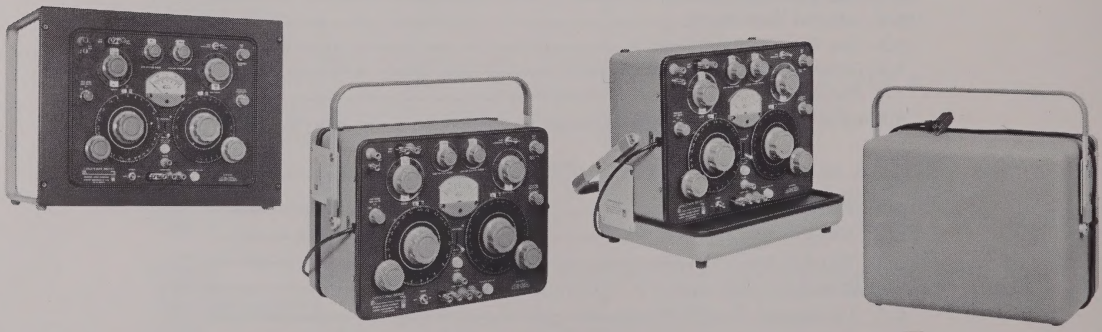


Figure 1-1. Type 1617 Capacitance Bridge, shown with the carrying case set in various forms.



WARNING

It is possible to apply lethal voltages across a capacitor by means of the Type 1617 Capacitance Bridge. The energy stored in the unknown capacitor, and even in the internal capacitor, can be extremely dangerous to the operator; please follow the instructions carefully. Never connect or disconnect anything at the UNKNOWN terminals unless the BIAS CHARGE-DISCHARGE switch is on DISCHARGE and the two warning lamps are off. When no bias voltage is applied, set the VOLTAGE RANGE switch to 2 V, the BIAS ADJ to EXT and the BIAS CHARGE-DISCHARGE switch to DISCHARGE. When operating the bridge at high voltage level, use every possible precaution to avoid contact with the UNKNOWN terminals, or the positive terminal of the capacitor under test.

SECTION 1

INTRODUCTION

1.1 PURPOSE.

The Type 1617 Capacitance Bridge, an entirely self-contained system, measures capacitance and dissipation factor of practically any capacitor, and is particulary designed to test tantalum or aluminum electrolytic capacitors at 120 Hz per MIL and EIA specification (refer to specifications).

It measures dc leakage current with a resolution of about 1 μA and in general is a good 1% capacitance bridge. It permits two-, three-, four- and even five-terminal measurements of capacitance and dielectric loss of insulating materials, cables, and transformers, even if remotely located.

1.2 DESCRIPTION.

The Type 1617 Capacitance Bridge is a modified form of the standard series-RC bridge. It operates from conventional 60-Hz power lines (50-Hz versions available), and is completely self-contained, including a 120-Hz generator, a selective detector, and a dc bias. Provisions have also been made for use of an external ac generator and dc bias supply. Accuracy is 1% between 40 Hz and 1kHz over most of the capacitance range.

To achieve the 1% accuracy over this wide capacitance range, 3- and 4-terminal connections as well as 2-terminal connections are provided. On high-capacitance ranges, where impedance is so low that leads have a significant effect on the D reading, a 4-terminal connection can be used. On low-capacitance ranges, where stray capacitance may cause a significant error in C measurement, a 3-terminal connection may be used.

Because the internally generated polarizing voltage can be as high as 600 volts, two panel lights are provided as safety features, one to indicate that the biasing switch is thrown, the other to indicate that the charge on the unknown capacitor exceeds 1 volt.

1.3 ACCESSORIES SUPPLIED.

Table 1-1 lists the accessories supplied with the Type 1617 bridge.

Table 1-1
Accessories Supplied

Quantity	*Description*	*Part Number*
1	Cable assembly for guarded measurements	1617-2200
1	Cable assembly for 4-terminal measurements	1617-2210
2	Fuses, 0.2 A for 115-V operation, or	5330-0600
	0.1 A for 230- V operation	5330-0400

1.4 CONTROLS, CONNECTORS, AND INDICATORS (Figure 1-2).

Table 1-2 lists and describes front-panel controls, connectors and indicators on the Type 1617 bridge.

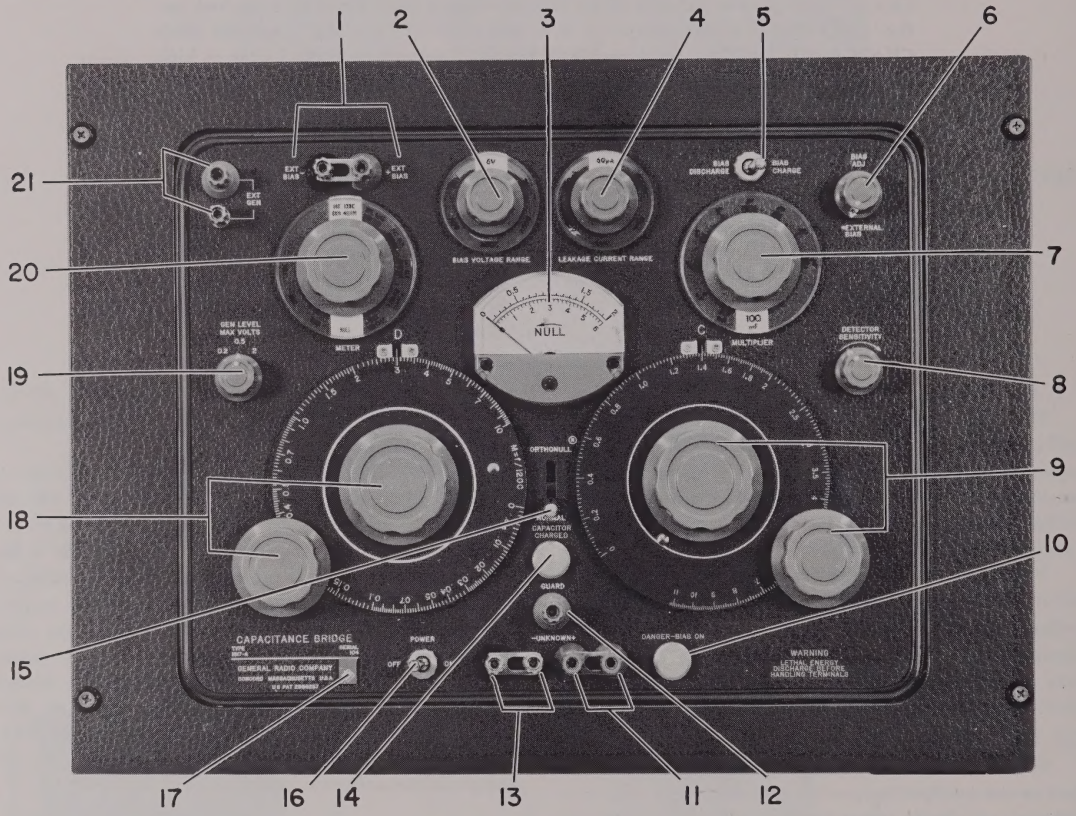


Figure 1-2. Controls, connectors and indicators.

NOTE

The exterior appearance of this instrument differs from the photographs shown in the instruction manual. The light-gray finish, snap-on knobs, etc. represent significant design advances for added user convenience and longer instrument life.

Where possible, extra vernier-adjustment knobs have been eliminated from potentiometer controls with calibrated dials (see 18, Figure 1-2).

Table 1-2

Controls, Connectors and Indicators
(See Figure 1-2)

Ref	*Control*	*Type*	*Function*
1	EXT BIAS	Binding-post pair, 3/4-inch spaced	Allows connection of an external dc-bias voltage of up to 800 V.
2	BIAS VOLTAGE RANGE	Six-position rotary switch	Selects internal dc bias supply and corresponding meter ranges; 2, 6, 20, 60, 200, or 600 V.
3	NULL meter	50-μF meter	Measures detector output voltage, (null), bias voltage, or leakage current as determined by function control.
4	LEAKAGE CURRENT RANGE	Six-position rotary switch	Selects leakage-current range of NULL meter when function control (20) is set to LEAKAGE CURRENT. Full-scale currents are 60, 200, or 600 μA; 2, 6, or 20 mA.
5	BIAS switch	Two-position toggle switch	Allows internal or external bias voltage to be applied to or removed from capacitor under test.
6	BIAS ADJUST	Combination switch-potentiometer	Extreme counter-clockwise position (EXTERNAL BIAS) allows application of bias from external power supply via EXT BIAS terminals. Over remainder of range, allows continuous adjustment of internal dc bias from 0 to maximum value determined by BIAS VOLTAGE RANGE control.
7	MULTIPLIER	Ten-position rotary switch	Multiplier control for capacitance dial: 100 pF; 1, 10, or 100 nF; 1, 10, or 100 μF; 1, 10, or 100 mF.
8	DETECTOR SENSITIVITY	Potentiometer control	Provides continuously adjustable detector sensitivity for bridge measurement.
9	C dial	Potentiometer control with calibrated dial	Main balance control for capacitance.
10	DANGER-BIAS ON	Incandescent lamp with white lens	Lit when BIAS switch is in CHARGE position, to warn of possible lethal energy at UNKNOWN terminals.
11	+UNKNOWN	Binding-post pair, 3/4-inch spaced	Allows connection of positive side of unknown capacitor.
12	GUARD	Single binding post	Furnishes guard voltage for 3-terminal measurements to reduce stray capacitance.
13	-UNKNOWN	Binding-post pair, 3/4-inch spaced	Allows connection of negative side of unknown capacitor.
14	CAPACITOR CHARGED	Incandescent lamp with white lens	Lit when charge on capacitor exceeds one volt.
15	ORTHONULL	Mechanical lever	Engages Orthonull mechanism to simplify balance operation, to avoid false nulls and sliding balances with lossy capacitors (D>1).
16	POWER	Two-position toggle switch	Energizes instrument.
17	Pilot Lamp	Incandescent lamp with GR monogram	Lit when POWER switch is ON.
18	D dial	Potentiometer control with calibrated dial	Main balance control for dissipation factor.
19	GEN LEVEL MAX VOLTS	Three-position rotary switch	Selects generator voltage applied to the bridge: 0.2, 0.5, or 2 V, rms. The ac voltage on the unknown capacitor will always be less.
20	Function switch	Six-position rotary switch	Selects generator source and polarity (INT NORM, INT REV, EXT NORM, or EXT REV) and meter indication (NULL BIAS VOLTAGE, or LEAKAGE CURRENT).
21	EXT GEN	Binding-post pair, 3/4-inch spaced	Allows connection of an external generator; 40 Hz to 1 kHz, 1 W, max.

1.5 SYMBOLS, ABBREVIATIONS, AND DEFINITIONS.

Definitions for symbols used on the panel of the Type 1617 and for abbreviations used in this instruction manual are as follows:

C capacitance (see below for units)

C_s series capacitance $C_s = (1 + D^2)\, C_p$

C_p parallel capacitance $C_p = \frac{1}{1 + D^2}\, C_s$

L inductance (see below for units)

R resistance, the real part of an impedance – (see below for units)

R_s series resistance

R_p parallel resistance

X reactance, the imaginary part of an impedance

Z impedance

D dissipation factor $\frac{R}{X} = \frac{1}{Q}$

for capacitors = $\omega C_s R_s = \frac{1}{\omega C_p R_p}$

PF power factor = $\frac{R}{|Z|} = \frac{R}{\sqrt{R^2 + X^2}} = \frac{D}{\sqrt{1 + D^2}}$

ESR equivalent series resistance = $R_s = \frac{D}{\omega C_s}$

f frequency in hertz (Hz)

ω angular frequency (rad/sec) = $\omega = 2\pi f$

F farad, unit of capacitance

mF millifarad = 10^{-3}F = $10^{3}\mu$F

μF microfarad = 10^{-6}F = 10^{3}nF = 10^{6}pF

nF nanofarad = 10^{-9}F = $10^{-3}\mu$F = 10^{3}pF

pF picofarad = 10^{-12}F = $10^{-6}\mu$F = 10^{-3}nF

Ω ohm, unit of resistance

mΩ milliohm = $10^{-3}\Omega$

kΩ kilohm = $10^{3}\Omega$

MΩ megohm = $10^{6}\Omega$ = 10^{3}kΩ

H henry, unit of inductance

mH millihenry = 10^{-3}H

μH microhenry = 10^{-6}H

nH nanohenry = 10^{-9}H

1.6 OPERATOR SAFETY.

Measurements on charged capacitors are inherently dangerous. The Type 1617 Capacitance Bridge, being a self-contained instrument, is naturally safer than a temporary clip-lead set up and all possible safety features were included in its design. The operator must follow instructions at all times to ensure safe use of the instrument.

Connect or disconnect the capacitor to be tested only when both warning lights are off. This means that bias is not applied (CHARGE-DISCHARGE switch on the DISCHARGE position) and that there is less than 1 volt across the capacitor.

Do not rely solely on the warning lights (the lamps might burn out), especially if repeated measurements are to be made; use insulated test clips, rubber gloves, and a chair insulated from the ground.

Several capacitors in the instrument itself can carry charges of lethal energy; they are safe only when both warning lights are off.

When no bias is to be applied, set the VOLTAGE/RANGE switch to 2 V, the BIAS ADJ to EXT, and the CHARGE-DISCHARGE switch to DISCHARGE. Under these conditions, an accidental change in the setting of one of the controls will not endanger the operator.

If the bridge is never going to be used with internal dc bias, the bias supply can be disabled by disconnection of the leads to pins 10 through 15 on the power-transformer plate (see Figure 6-2). If only the lower bias voltages are to be used, the higher voltages can be eliminated by disconnection of pin 12 of the power transformer and by shorting the appropriate resistor (Table 1-3).

Table 1-3
Bias Range Variation

Resistor Shorted	*Value*	*Range Eliminated*
R115	402 K	600 V
R154	140 K	200 V
R153	40.2 K	60 V
R152	14 K	20 V
R151	4.02K	6 V

SECTION **2**

INSTALLATION

2.1 GENERAL.

2.1.1 DIMENSIONS.

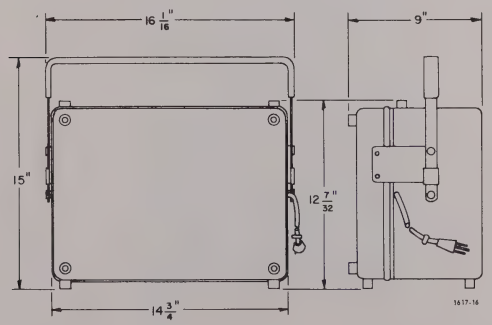
The over-all dimensions for the bridge are shown in Figure 2-1.

2.1.2 ENVIRONMENTAL CONSIDERATIONS.

The Type 1617 bridge is designed to operate at ambient temperatures from 0 to 50 °C and to be stored at temperatures from -40 to +70 °.

2.2 MOUNTING.

The Type 1617 bridge is supplied in either of two mechanical configurations, portable or rack mountable. An adaptor set (P/N 0481-9759) converts the portable model to the rack model. Each adaptor set contains a relay-rack panel, a hardware set, and instructions for rack mounting. A rack model can be stack mounted for bench use in combinations with other instruments.



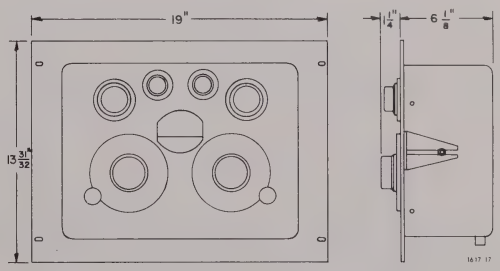


Figure 2-1. Dimensions of the Type 1617 bridge in the portable and rack models.

2.2.1 PORTABLE TO RACK MOUNT CONVERSION. (Figure 2-2).

To convert from portable to rack mount:

a. Open the instrument fully to its horizontal position.

b. Remove the 10-32 screws (A) that secure the instrument to the cabinet and lift the instrument out of the cabinet.

c. Remove the pivot studs (B) and lift the cabinet off the cover-and-handle assembly.

d. Attach 1/4-28 screws (C) in place of the pivot screws. Secure them with 1/4-inch lockwashers and nuts and then add a 1/4-inch flatwasher to each screw.

e. Replace the instrument in the cabinet and secure it with the 10-32 screws (A), removed earlier.

f. Attach the brackets (D) to the panel with no. 10 lockwashers and nuts; do not tighten.

g. Add a no. 10 flat washer to the top and bottom lugs, and attach the plates (E) with no. 10 lockwashers and nuts; do not tighten.

h. Place the panel over the instrument; slide the slit in each bracket over the 1/4-28 screw (C), keeping the flatwasher between the instrument and the bracket.

i. Slide the plates over the gasket, align the assembly, and tighten all nuts.

2.2.2 RACK-TO-PORTABLE CONVERSION.

To convert a rack instrument for portable use, follow the reverse procedure given in paragraph 2.2.1. The parts required for this conversion are listed in Table 2-1.

Table 2-1

Parts Required for Rack-To-Portable Conversion

Quantity	*Description*	*Part No.*
1	Handle and Bracket Assembly	1617-2010
1	Cover Assembly	4170-2086
2	Pivot Stud	4170-1000
2	Plate Nut	4170-1376
2	Spacer	4170-0700
2	Screw, No. 1/4-28, 3/8	7040-0400
4	Screw, No. 10-32, 3/8	7080-1000
4	Washer	8040-2400
2	Washer	8050-0100

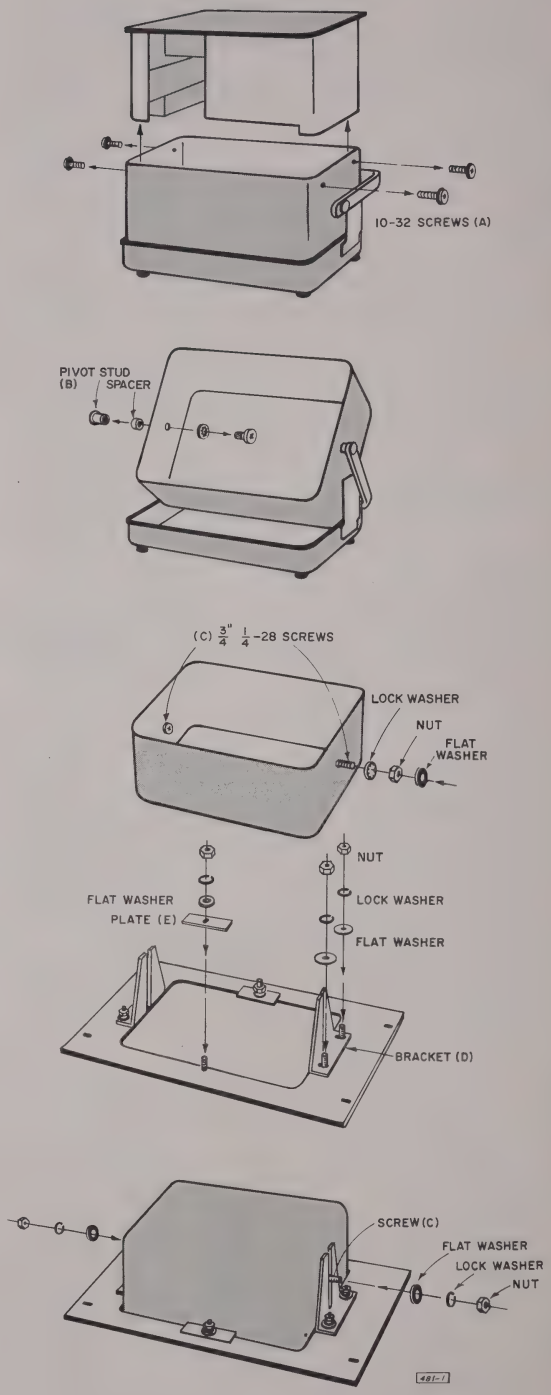


Figure 2-2. Procedure to rack mount a portable model.

2.2.3 STACK MOUNTING.

A rack model can also be stack mounted with other GR relay-rack instruments fitted with end frames for bench use. Stack-mounted accessories required for the Type 1617 are listed in Table 2-2 and mounting instructions (Form 5301-0145A) are available with the accessories.

Table 2-2

Stack-Mounting Accessories Required

Quantity	*Part Number*	*Description*
1	5310-9682	End-frame set
4	7660-2015	Spacers, 15/32-inch high
4	7080-2900	Screws, 10-32 x 7/8
4	8040-2400	Lockwashers, no. 10
4	5810-3300	Nuts, no. 10

2.3 POWER CONNECTION.

2.3.1 GENERAL.

Use the attached three-wire power cord to connect the bridge to a source of power as indicated on the tag located on the cabinet beneath the power cord (Figure 2-3). The long cylindrical pin (ground) is connected directly to the metal case of the instrument, hence to the EXT GEN ground connector and -UNKNOWN ground connector on the front panel.

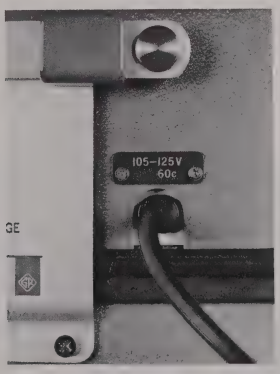


Figure 2-3. Indication of the source of power to be used.

2.3.2 115-VOLT LINE.

Power required is 105 to 125 V, 50 or 60 Hz (depending on model of bridge), 18 W. An input plate for 115-V operation, P/N 5590-1667, is used for 60-Hz models; P/N 5590-1163 for 50-Hz models. It attaches to the cabinet beneath the power cord by means of two 4-40 x 3/16 screws with attached lockwashers, P/N 7090-4030. On the terminal plate of the power transformer (Figure 6-2), terminal 1 is connected to terminal 3 and terminal 2 to terminal 4. Fuses for F501 and F502 are 0.2 A, P/N 5330-0600 each (Figure 2-4).

2.3.3 230-VOLT LINE.

Power required is 210 to 250 V, 50 or 60 Hz (depending on model of bridge), 18 W. An input plate for 230-V operation, P/N 5590-0700, is used for 60-Hz models; P/N 5590-1666 is used for 50-Hz models. It attaches to the cabinet beneath the power cord by means of two 4-40 x 3/16 screws with attached lockwashers, P/N 7090-4030. On the terminal plate of the power transformer, terminal 2 is connected to terminal 3. Fuses for F501 and F502 are 0.1 A, P/N 5330-0400 each (Figure 2-4).

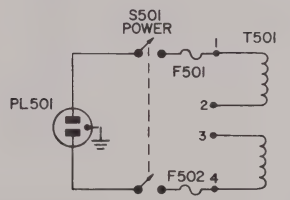


Figure 2-4. The transformer connections for 115- or 230-V operation.

2.3.4 LINE-FREQUENCY CONVERSION.

Conversion from 60-Hz to 50-Hz line-frequency operation is possible but not simple. Table 2-3 lists the parts to be changed.

2.3.5 CONNECTIONS.

The EXT GEN, EXT BIAS and UNKNOWN terminals are standard 3/4-inch-spaced binding posts which ac-

cept banana plugs, standard telephone tips, alligator clips, crocodile clips spade terminals and all wire size up to number ten (see Figure 2-5).

Two plug-in cable assemblies are supplied with the bridge expressly for the UNKNOWN terminal.

The two-cable assembly (Figure 3-2) has a shielded positive terminal. The shield is connected to the guard and the two positive and the two negative terminals are linked internally. It should be used for three-terminal measurements (refer to paragraph 3.1).

The four-cable assembly (Figure 3-3) is used for four terminal measurements (refer to paragraph 3.1). The cables of both assemblies are terminated in clip leads in an insulated rubber sleeve.

Table 2-3

Components that Differ in the 50- and 60-Hz Model

	Ref. Desig.	*Description*	*Part Number*
60-Hz Model	C204	Capacitor, plastic, 0.1 μF ±2% 100 V	4860-8251
	C205	Capacitor, plastic, 0.1 μF ±2% 100 V	4860-8251
	C411	Capacitor, plastic, 0.02 μF ±1% 100 V	4860-7853
	C412	Capacitor, plastic, 0.02 μF ±1% 100 V	4860-7853
	C413	Capacitor, plastic, 0.04 μF ±1% 100 V	4860-7836
	for R102	Knob and dial assembly	1617-1250
	for S102	Knob and dial assembly	1617-2170
		115-V power-input plate, 60-Hz	5590-1667
		230-V power-input plate, 60-Hz	5590-0700
	Ref. Desig.	*Description*	*Part Number*
50-Hz Model	C204	Capacitor, plastic, 0.121 μF ±2% 100 V	4860-7908
	C205	Capacitor, plastic, 0.121 μF ±2% 100 V	4860-7908
	C411	Capacitor, plastic, 0.0243 μF ±1% 100 V	4860-7833
	C412	Capacitor, plastic, 0.0243 μF ±1% 100 V	4860-7833
	C413	Capacitor, plastic, 0.0475 μF ±1% 100 V	4860-8204
	for R102	Knob and dial assembly	1617-1260
	for S102	Knob and dial assembly	1617-2190
		115-V power-input plate, 50-Hz	5590-1663
		230-V power-input plate, 50-Hz	5590-1666

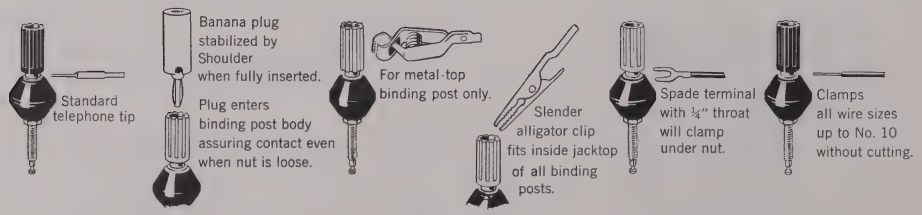

Standard telephone tip
Banana plug stabilized by Shoulder when fully inserted.
Plug enters binding post body assuring contact even when nut is loose.
For metal-top binding post only.
Slender alligator clip fits inside jacktop of all binding posts.
Spade terminal with ¼" throat will clamp under nut.
Clamps all wire sizes up to No. 10 without cutting.

Figure 2-5. Methods of connection to the measurement terminals.

SECTION 3

OPERATING PROCEDURE

3.1 CONNECTION OF THE UNKNOWN CAPACITOR.

3.1.1 GENERAL.

The panel of the Type 1617 Capacitance Bridge offers five separate terminals at which to connect the unknown. There are two current terminals, two potential terminals and one guard terminal; two shorting links are also provided Figure 3-1. This array permits two-, three-, four-, and five-terminal measurements, as dictated by the value of the unknown and its location.

3.1.2 LOW-VALUED CAPACITORS.

In this range (less than 10 nF), since shunt stray capacitance is apt to introduce an important error, three-terminal connections should be made. The supplied plug-in cable assembly (P/N 1617-2200) achieves this connection simply (Figure 3-2). The linkage of the positive and the negative terminals is achieved internally in the assembly. It can also be done as follows: Connect the inner conductor of a shielded cable to either positive terminal, the shield of the cable to the guard terminal, and any clip lead to either negative terminal (both positive and negative terminals should be linked). Then connect the unknown at the end of the two cables and proceed with the measurement.

The residual ("zero") of the bridge (i.e., the reading of the C dial when the bridge is balanced while on the lowest range with the unknown disconnected) is to be subtracted from the C reading. It is small (about 4 pF) and can be considered negligible on the other ranges.

3.1.3 MEDIUM-VALUED CAPACITORS.

Capacitance measurements in this range (about 10ηF to 100μF) are not appreciable affected by shunt capacitance or series impedances, unless the leads are more than a few feet long. Therefore, most any type of clip leads may be used although the two-lead cable assembly supplied, P/N 1617-2200, is particularly convenient.

If the leads are very long, the lower capacitance values should be connected with a guarded, shielded cable and the higher values should use a four-lead connection (see paragraph 4.5.1).

NOTE

In 2- and 3-terminal measurements, when the assembly is not used, the bridge will not balance unless the shorting links are connected.

Figure 3-1. UNKNOWN and GUARD terminals on the bridge.

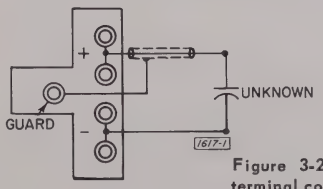


Figure 3-2. Schematic of the 3-terminal connection (guarded), using the two-lead plug-in assembly (P/N 1617-2200).

3.1.4 HIGH-VALUED CAPACITORS.

For the range 100μF to 10mF of capacitance, the lead impedance might introduce a sizeable D error in a two-terminal measurement. For example, 100μF measured with the supplied two-lead cable assembly at 120 Hz gives a D reading higher than the actual value by 0.005.

Four-terminal measurements are necessary for better D accuracy. The bridge connection is made convenient with the supplied cable assembly (P/N 1617-2210). When a four-lead connection is made to a capacitor (Figure 3-3), the bridge will measure the effective capacitance and loss of the impedance between the junction of the two positive leads and the junction of the two negative ones. In effect, the unknown starts where it becomes two-terminal. Figure 3-4 shows different types of four-terminal connections, the effective impedance measured by the bridge being from A to B.

NOTE

Disconnect the shorting links when making four-terminal measurements.

3.1.5 VERY HIGH VALUED CAPACITORS.

Four-terminal connections should be used on very large capacitors (10 mF to 1 F) not only to avoid large D errors due to lead resistance, but also to avoid capacitance errors caused by lead inductance.

While a four-lead connection removes the effect of the resistance and self-inductance of each lead, some care must be used to avoid mutual inductance between the outer two ("current") leads and the inner two ("potential") leads; see Figure 3-5. Mutual inductance here causes an induced voltage that increases the effective value of the unknown. This mutual inductance can be greatly reduced by twisting together either the two outer leads or the two inner leads as shown in Figure 3-6.

This precaution against mutual inductance is also important when lower capacitance is measured at higher frequencies, because the error is a function of $\omega^2 MC_x$, where M is the total mutual inductance. There is always some mutual inductance present at the bridge terminals and this limits the range of the bridge at higher frequencies.

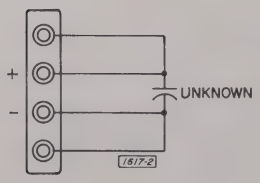


Figure 3-3. A 4-terminal connection using the four-lead plug-in assembly.

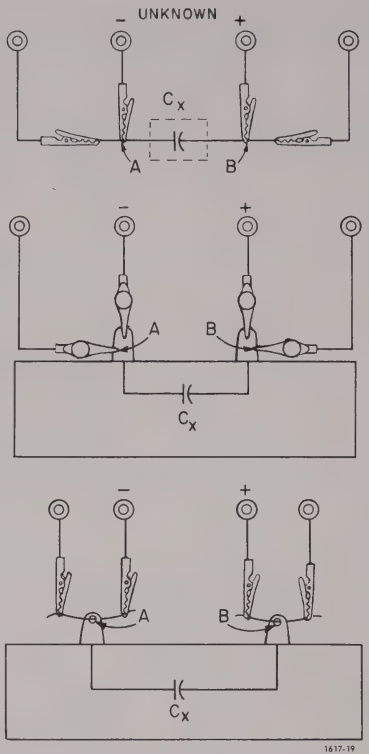


Figure 3-4. Different types of 4-terminal connections. The unknown is measured from A to B.

NOTE

The ranges indicated in the above paragraphs are quite arbitrary and are intended only as guides. The type of connection used for a given capacitance might also depend on the length of the leads, and the D and C accuracies desired.

3.2 CAPACITANCE MEASUREMENT PROCEDURE – INTERNAL GENERATOR.

3.2.1 NO BIAS APPLIED.

To measure an unknown capacitor with no bias applied proceed as follows:

Safety measures:

Place the BIAS CHARGE-DISCHARGE switch at DISCHARGE.

Set BIAS ADJ to EXT BIAS (EXT BIAS terminals must be shorted).

Set the BIAS VOLTAGE RANGE switch to 2 V.

a. Connect the bridge to the line and turn POWER on.

b. Connect the unknown capacitor (refer to paragraph 3.1).

c. Set the function switch to INT 120C* either NORMAL or REVERSE.

d. Select the maximum AC voltage desired on GEN LEVEL MAX VOLTS.

e. Turn the DETECTOR SENSITIVITY counterclockwise (minimum sensitivity).

f. If the approximate value is known, set the MULTIPLIER switch accordingly.

g. Increase the sensitivity (DETECTOR SENSITIVITY clockwise) to give an upscale deflection.

h. Adjust the C and D dials to obtain a minimum deflection on the NULL meter. Repeat this process until the best null for the highest feasible sensitivity is obtained.

NOTE

When the D of the unknown is greater than one, use the Orthonull® (ganging the C and D dials) will avoid false nulls and speed the balance.

i. Multiply the C-dial setting by the MULTIPLIER setting to obtain the capacitance of the unknown.

j. Read the dissipation factor directly on the D dial.

3.2.2 BIAS APPLIED.

To measure an unknown capacitor with bias applied, proceed as follows:

a. Move the BIAS CHARGE-DISCHARGE switch to DISCHARGE.

b. Connect the bridge to the line and turn POWER on.

c. Connect the unknown (refer to paragraph 3.1).

d. Set the function switch to BIAS VOLTAGE.

e. Set BIAS VOLTAGE RANGE switch on the desired range.

f. Move the BIAS CHARGE/DISCHARGE switch to CHARGE.

g. Adjust the BIAS ADJ knob until the meter reads the desired voltage (do not exceed the rating of the unknown).

h. Proceed with step c through j of paragraph 3.2.1.

i. Throw the CHARGE/DISCHARGE switch on DISCHARGE before disconnecting the unknown.

3.2.3 RANGE AND ACCURACY.

With the internal generator, the C accuracy is ±1% ±1 pF from 0 to 0.11 F. The residual ("zero of the bridge") to be subtracted from the reading is approximately 4 pF. From 0.11 to 1.1 F, the accuracy becomes ±2%. The D accuracy (±0.001 ±0.01 C in F ±2%) depends on C. This naturally assumes that the correct connections (refer to paragraph 3.1) have been used to minimize errors.

*The notation C (cycles per second) is equivalent to Hz (hertz).

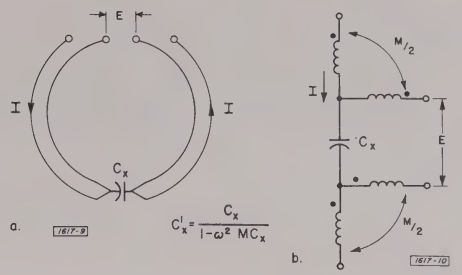


Figure 3-5. When "current" and "potential" leads form concentric loops (left), the resulting mutual inductance (right) affects the value of the capacitance being measured.

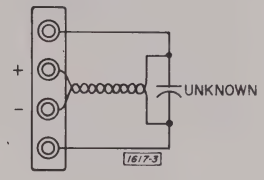


Figure 3-6. Reduction of the effect of mutual inductance in the leads.

When bias voltage is applied, the accuracy specifications are the same, but the sensitivity of the bridge is lessened by the impedance of the internal capacitor always across the bias supply (refer to paragraph 5.5).

3.3 LEAKAGE CURRENT MEASUREMENT.

3.3.1 GENERAL.

The leakage current through capacitors of most types is a function of time. A common practice for many types of capacitors is to use the value obtained after voltage is applied for two minutes, but other soaking times are also used so that this parameter should be specified.

The current measuring range of the Type 1617 is limited to 60-μA to 20-mA, full scale; 0.5 μA can be resolved. This range is sufficient for most aluminum capacitors and some tantalum types. An external microammeter may be used for lower leakage currents (refer to paragraph 4.2). The available current from the internal power supply limits the maximum to about 15 mA. An external power supply and meter should be used if the leakage is higher than this.

3.3.2 MEASUREMENT PROCEDURE.

The procedure is as follows:

a. Perform steps a through g of paragraph 3.2.2.

b. Set the function switch to LEAKAGE CURRENT.

c. Set the LEAKAGE CURRENT RANGE switch on a suitable range.

d. Read the leakage current on the meter; the full-scale reading is that set in the preceding step.

e. Throw the BIAS CHARGE-DISCHARGE switch to DISCHARGE before disconnection of the unknown.

3.3.3 CHARGING TIME.

The time required to charge a capacitor from a current-linked supply is:

$$t = \frac{CV}{I} \text{ (seconds, farads, volts, and amperes)}$$

The capacitance is the sum of the unknown capacitance and the internal power-supply by-pass capacitance. The current is the difference between the maximum power supply current, approximately 15 mA, and the leakage current in both capacitors. For low-energy-unknown capacitors, the charging time is that of the internal capacitor, which is about 4 seconds. For high-energy capacitors, the time constant may become much longer. If charging is too slow, an external supply of higher current rating should be used.

If the internal power supply has not been used in some time, the by-pass capacitors may become somewhat leaky, resulting in very slow charging until they are reformed. This is particularly noticeable on the higher voltage ranges. Note that if the total leakage of the unknown and by-pass capacitors exceeds the available current, the voltage will never reach its correct value.

The charging time also depends on the value of the ratio-arm resistor in series with the unknown, but this delay will not be noticed on the voltmeter which reads the total voltage applied to the bridge (see Figure 3-7). However, if the capacitance range switch is set to the correct capacitance range, this time constant is negligible.

3.3.4 METER RESPONSE.

The ammeter response is purposely slow in order to protect the meter from pinning when it passes excessive current (for example, when the bias is discharged with the ammeter in the circuit). The meter indication may become very slow, when very large capacitors with low leakage are measured, because the meter time constant is a function of the meter-range resistor and the unknown capacitor.

The voltage applied to the unknown during leakage-current measurements is slightly reduced by the ammeter voltage drop. This drop is proportional to the meter reading and is 0.2 V at full scale. This voltage change is of little consequence except at very low applied voltages. However, it does introduce a small transient in the ammeter which may indicate the current flow necessary to re-establish equilibrum.

3.4 VOLTAGE MEASUREMENT ACCURACY.

The voltmeter indicates 2-V to 600-V full scale in six ranges with an accuracy of ±3%. The voltage measured is the voltage applied to the bridge input and, in most cases, this is the voltage across the unknown. However, when a very leaky capacitor is measured, the voltage drop in the ratio-arm resistor caused by the high-leakage current may result in the actual voltage on the capacitor being less than the voltage indicated (see Figure 3-7). In order to obtain the proper voltage in the capacitor, the voltmeter must be set to read $E_c (1 + \frac{R_A}{R_e})$. This difficulty is very rarely encountered if the capacitance switch is set to the correct range.

3.5 MAXIMUM DISCHARGE ENERGY.

Theoretically, the maximum energy on an unknown capacitor connected to the bridge could be 320,000 joules (800 V in 1 F). This energy would certainly destroy the discharge resistor and switch if internal-discharge circuits were used. Fortunately, nobody makes a capacitor of such capability. However, large capacitors are made for special purposes (such as welding) that can damage the discharge resistors, so that an energy limit is necessary. Therefore, the maximum voltage that should be discharged by the internal circuit is given in Table 3-1.

Also, if an external bias supply is used, the rate of charging and discharging may be high enough to overheat the discharge resistors, even though the limits of Table 3-1 are not exceeded. The average power dissipated should be limited to 5 watts.

Figure 3-7. To change Cx to Ec, E must be $E_c (1 + \frac{R_A}{R_e})$.

Table 3-1

Maximum Safe Voltages at Various Capacitance Ranges

Capacitance Range	*Maximum Voltage*
0 to 100 μF	*800 V*
0.1 to 1 mF	*400 V*
1 to 10 mF	*100 V*
10 to 100 mF	*20 V*
0.1 to 1 F	*6 V*

SECTION 4

SPECIAL MEASUREMENTS

4.1 USE OF AN EXTERNAL GENERATOR.

4.1.1 CONNECTION.

The preferred connection for an external generator is at the EXT GEN terminals. The terminals are connected to the primary of the input transformer whose secondary winding is selected by the GEN LEVEL switch (Figure 4-1). If 5V, rms, is applied to the terminals, the voltage applied to the bridge will be as indicated by this switch. Note that the input to the bridge may be reversed by the function switch to check for stray coupling effects (refer to paragraph 4.4).

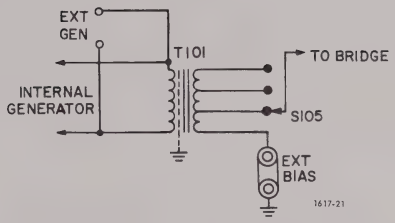


Figure 4-1. Location of the external generator connection (EXT GEN terminals).

At low frequencies, more voltage may be applied to the bridge if the external generator is connected to the EXT BIAS terminals (Figure 4-2, see also paragraph 4.1.3). Use a shielded lead to avoid coupling to the unknown and, because the bridge is grounded, do not ground either side of the oscillator, to avoid ground loops.* If, however, bias has to be applied, it can be done as shown in Figure 4-3.

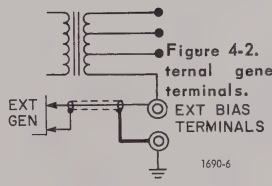


Figure 4-2. Connection of the external generator at the EXT BIAS terminals.

The GR 1311 Audio Oscillator is recommended as an ideal external generator for driving the Type 1617.

4.1.2 RANGE AND ACCURACY.

Table 4-1 indicates the nominal capacitance range of the Type 1617 Capacitance Bridge for better than 2% accuracy at different frequencies above 120 Hz. The low end of the capacitance range is limited to 500 pF above 2 kHz, because of the frequency characteristic

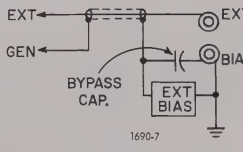


Figure 4-3. External generator and bias supply at the EXT BIAS terminals.

*With oscillators which have one side of the output tied to the case, do not use the third wire of the power cord, so as not to ground the case.

Table 4-1

RANGE LIMITS At Different Frequencies (Less Than 2% Error)

Frequency	*Low Limit**	*High Limit***
120 Hz	50 pF	1.1 F
200 Hz	50 pF	0.5 F
500 Hz	50 pF	80 mF
1 kHz	150 pF	20 mF
2 kHz	500 pF	5 mF
5 kHz	500 pF	800 μF
10 kHz	500 pF	200 μF

*After zero correction.
**4-terminal measurement with twisted leads.

of the 10 MΩ ratio arm (R_A). The high end is limited by the mutual inductance in the leads and between the terminals.

The low-frequency limit is approximately 20 Hz, at which point the meter starts to follow individual cycles. Full accuracy below 30 Hz is difficult to obtain on the lowest and highest ranges, because the limit on the input voltage (refer to paragraph 4.1.3) limits the sensitivity. At low frequencies, many low-powered oscillators will not drive the input inductance (approximately 50 mH) hard enough to give sufficient sensitivity. The D accuracy is ±0.001 ±0.01 C(in F) ±2%, from 40 to 120 Hz, and $[\pm 0.001 \pm 0.01\ C(\text{in F})]\ \frac{f_{Hz}}{120} \pm 2\%$, above 120 Hz.

4.1.3 MAXIMUM AC VOLTAGE AND POWER.

The maximum voltage that should be applied to the EXT GEN terminals is $\frac{1}{10} f_{Hz}$ or 10 V, rms, whichever is less. The maximum ac applied to the EXT BIAS terminals is 4 V, rms. Actually, more voltage (but less than 100 V) may be applied to the bridge when the C dial is set up-scale as long as the voltage on the UNKNOWN does not exceed 4 V (which would overdrive the guard amplifier).

Thus, the above fixed limits may be multiplied by:

$$\sqrt{1 + (0.0063 \times f \times C \text{ dial reading})^2}$$

The power input should be limited to 1 watt. (The output of the GR 1311 is limited to 1 watt.)

4.1.4 MEASUREMENT PROCEDURE.

The procedure is the same as with the internal generator except that the function switch must be set to EXT GEN NORMAL or REVERSE, and the D reading must be multiplied by $\frac{f_{Hz}}{120}$. The generator level is adjusted on the external generator.

4.2 USE OF AN EXTERNAL MICROAMMETER.

The lowest range of the microammeter on the Type 1617 Capacitance Bridge is 60 μA, full scale. Some electrolytic capacitors (tantalum, in particular, and many other types) will require more sensitivity. This is easily accomplished by use of a sensitive external meter, such as the Type 1230 Electrometer (measures from ±1 mA down to 0.3 $\mu\mu$A, or 0.3 x 10^{-12} A, full scale). The Weston 1946T (available in 5, 10 or 20-μA, full-scale versions, with 2% accuracy) or the Westinghouse 371 (3% accuracy, 20 μA full scale), are acceptable substitutes.

Connect the external meter in series with the unknown, with its negative terminal to the negative terminal of the bridge (Figure 4-4). It is now part of the unknown and has to be shorted out in a capacitance measurement to avoid error, or when charging the capacitor to avoid overload.

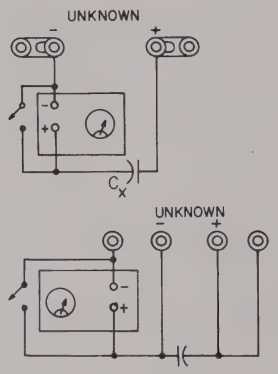


Figure 4-4. Use of an external ammeter for 2-terminal measurement, (top), 4-terminal measurement (bottom).

4.3 EXTERNAL BIAS SUPPLY (Table 3-1).

The internal bias supply will apply up to 600 V to the unknown; up to 800 V can be applied by use of an external dc supply. To apply external bias:

a. Set the BIAS ADJ switch to EXTERNAL BIAS.

b. Remove the shorting link from the EXT BIAS terminals and connect the power supply to these terminals.

c. To preserve the sensitivity of the bridge, the effective ac impedance of the supply has to be very low, and this is ensured by placing a bypass capacitor as shown in Figure 4-5. This capacitor should be at least of the same order of magnitude as the unknown.

WARNING

The bypass capacitor has the same bias voltage across it as the unknown. Make sure the dc supply is off and the BIAS CHARGE-DISCHARGE switch is on DISCHARGE before disconnecting or connecting it.

The measurement procedure, once the external dc supply is connected, is the same as with the internal bias supply. The energy available from the external bias supply should be limited to 1 W so that if the unknown is shorted, the bridge ratio-arm resistor will not be damaged.

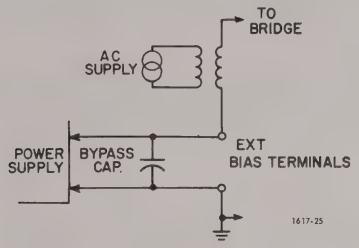


Figure 4-5. Connection of the external bias supply.

4.4 USE OF THE NORMAL/REVERSE POSITIONS.

Because the bridge test signal is synchronous with the power line, 120-Hz hum pickup will cause a bridge error. The NORMAL/REVERSE positions of the function switch allow the test signal to be reversed (Figure 4-6) with respect to the power line, so that the presence of pickup can be ascertained.

Should the D or C readings differ between balances on the NORMAL and REVERSE position, the best answer is the average of the two readings. This difficulty is most likely to occur on the lowest or highest ranges. Use the maximum possible signal level to reduce the effect.

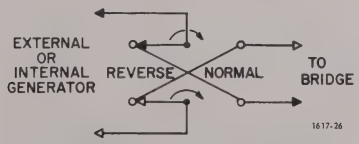


Figure 4-6. The reversing switch.

4.5 OTHER APPLICATIONS.

4.5.1 REMOTE MEASUREMENTS.

When long leads are used, the two principal sources of error are the lead impedance (it can be several ohms) and the stray capacitance. For D accuracy, four-lead connections are necessary, and to reduce the stray capacitances, the positive lead should be shielded and the shield guarded.

When both errors may be important, a five-terminal measurement can be made (Figure 4-7).

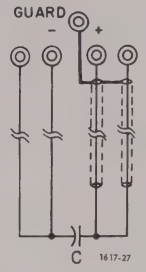


Figure 4-7. A 5-terminal connection.

4.5.2 INDUCTANCE MEASUREMENT.

Series Substitution Method. Inductance can be determined from the measurement of the net effective capacitance of the unknown inductor in series with a known capacitor of suitable value. The series capacitor must be small enough so that the net reactance of the combination is capacitive, and it must be large enough so that a significant change in effective capacitance results. Proceed as follows:

a. Connect the inductor and the capacitor in series (Figure 4-8) to the bridge.

b. Short circuit the inductor and balance the bridge. Observe the C and D readings. Call them C_1 and D_1.

c. Remove the short circuit and rebalance the bridge. Call the new readings C_2 and D_2.

d. Compute the series inductance (Ls) and the series resistance (Rs) from:

$$L_s = \frac{C_2 - C_1}{\omega^2 C_1 C_2} \qquad Rs = \frac{D_2 C_1 - D_1 C_2}{\omega C_1 C_2}$$

with the C's in farads and the D's in absolute values.

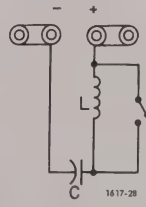


Figure 4-8. Inductance measurement by the series-substitution method.

Parallel substitution Method. For measurements using the parallel substitution method, proceed as follows:

a. Connect the unknown inductor and the capacitor in parallel (Figure 4-9).

b. Disconnect the high lead of the inductor and balance the bridge. Observe the C and D readings. Call them C_1 and D_1.

c. Connect the inductor and rebalance the bridge. Call the new reading C_2 and D_2.

d. Convert C_1 and C_2 To C_1 and C_2,the effective parallel value, with

$$C' = \frac{C}{1 + D^2}$$

e. Compute the parallel inductance (Lp) and resistance (Rp) from

$$L_p = \frac{1}{\omega^2 (C_1' - C_2')} \quad . \quad R_p = \frac{1}{\omega (D_2 C_2' - D_1 C_1')}$$

with the C's in farads and the D's in absolute values.

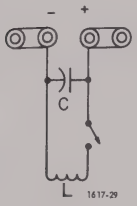


Figure 4-9. Inductance measurement by the parallel-substitution method.

4.5.3 SERIES AND PARALLEL COMPONENTS.

An impedance that is neither a pure reactance nor a pure resistance may be represented, at any specific frequency, by either a series or a parallel combination of resistance and reactance. The values of resistance and reactance used in the equivalent circuit depend on whether a series or a parallel combination is used. The equivalent circuits are shown in Figure 4-10.

The relationships between the circuit elements are:

$$Z = R_s + \frac{1}{j\omega C_s} = \frac{\frac{R_p}{j\omega C_p}}{R_p + \frac{1}{j\omega C_p}} = \frac{D^2 R_p + \frac{1}{j\omega C_p}}{1 + D^2}$$

$$D = \frac{1}{Q} = \omega R_s C_s = \frac{1}{\omega R_p C_p}$$

$$C_s = (1 + D^2) C_p; \quad C_p = \frac{1}{1 + D^2} C_s$$

$$R_s = \frac{D^2}{1 + D^2} R_p; \quad R_p = \frac{1 + D^2}{D^2} R_s$$

$$R_s = \frac{D}{\omega C_s}; \quad R_p = \frac{1}{\omega C_p D}$$

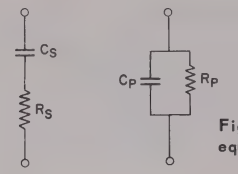


Figure 4-10. Series and parallel equivalent circuits.

4.5.4 DIELECTRIC SAMPLES MEASUREMENT.

The dielectric constant and dissipation factor of an insulating material can be determined from the measurement of the capacitance and dissipation factor of an elementary capacitor, with the material used as the insulating medium between metallic electrodes of suitable dimensions.

Two-Electrode Method. A simple two-electrode method is sufficient for most purposes. The procedure is as follows:

a. If possible, choose a sample of such shape and dimensions as to yield a capacitance of 100 pF or more. The calculation of dielectric constant is simplified if the thickness and area are easily measured and calculated, such as a disk or rectangle. If measurements are to be made at various frequencies, it is best to use sizes and shapes as specified in ASTMD-150 (available from American Society for Testing Materials, 260 Race Street, Philadelphia, Pennsylvania).

b. Measure and record the dimensions of the sample, and clean it thoroughly. (A mixture of half grain alcohol and half ether is recommended, unless either is a solvent for the material.)

c. When the sample is dry, apply a very thin film of refined petrolatum to one surface. Place a thin metal-foil electrode, preferably less than 1 mil thick, and larger than the sample, on this surface.

d. Press the electrode in place with a pad of cloth or squeegee roller and rub out any air bubbles, so that the foil is in intimate contact with the surface. Then trim the foil to the same size as the sample.

e. Apply the other electrode to the sample as described in steps c and d.

NOTE

An alternate method of forming electrodes is to brush a good silver paint (such as Dupont No. 4132 Silver Paste) on the sample and to dry it overnight at 60 °C. Such an electrode is porous to moisture, so that the dielectric can be conditioned at any desired relative humidity without removing the electrode.

f. Measure capacitance as described in paragraph 3.2.

g. Compute dielectric constant (to a first approximation) as follows:

$$K = \frac{4.45\,tC}{A}$$

where K is dielectric constant
t is thickness of the sample, in inches
C is measured capacitance, in pF
A is area of the electrodes, in square inches.

For a complete discussion of the effects of stray electric field at the edges of the electrodes, and the effect of the capacitance of the high electrode to ground, refer to ASTMD-150.

Three Electrodes Method. The guard arrangement (Figure 4-12) provides an electrical equivalent to a 3-terminal capacitance, and is measured as such.

4.5.5 1690 DIELECTRIC SAMPLE HOLDER.

The GR 1690 is a micrometer-driven sample holder for the measurement of dielectric constant and dissipation factor of 2-inch diameter, or less, discs of dielectric material in accordance with ASTM D-150. The sample holder accepts any flat sample that does not exceed a diameter of 2 inches, and a thickness of 0.3 inches. (Refer to the appendix.)

Although the 1690 was designed for use with a number of other GR measuring instruments, it can also be readily adapted for use with the 1617 bridge. See Figure 4-11 and proceed as follows:

a. Remove the 1690-P1 Adaptor from the bottom of the sample holder.

b. Thread banana plugs (provided) into hole A (high terminal) and hole B. Tighten securely.

c. Thread a 1¼-inch, No. 6-32 screw into hole C.

d. Connect shorting links between the UNKNOWN bridge terminals (see Figure 3-1).

CAUTION

The sample holder can be used on the 1617 only when the bridge is in its horizontal position with the panel facing upward. Handle the sample holder with care; do not drop the unit as this could result in damage to the precision micrometer adjustments.

e. Plug the 1690 into the UNKNOWN terminals on the bridge: the high plug (in hole A, Figure 4-11) into the + terminal and the other plug into the − terminal. (The screw, previously threaded into hole C, should be close to the near edge of the front panel of the bridge.)

f. Alternately adjust the top of the GUARD binding post and screw c until both provide firm support on both sides of the bridge terminals.

The 1690 is now mounted correctly on the bridge. Exercise reasonable care when loading samples, and check the support adjustments (step f) occasionally.

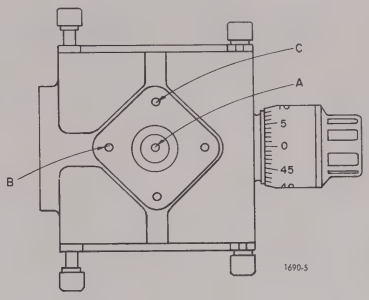


Figure 4-11. Bottom view of the 1690 Dielectric Sample Holder showing holes for banana plugs (A, B) and the stabilizing screw (C).

4.5.6 LIQUID INSULATION MEASUREMENT.

Liquid insulation, such as transformer oil, requires some type of cell for measurement of capacitance and dissipation factor. The cell in its simplest form can be a multiple-plate air capacitor immersed in the liquid, or a grounded cylindrical can with a slightly smaller insulated cylindrical electrode. Such cells do not allow the accurate calculation of dielectric constant, nor do they maintain a constant voltage gradient of the liquid. These difficulties are overcome by the use of a three-electrode cell, such as described in ASTMD-150. Such a cell is electrically equivalent to Figure 4-12 and permits a 3-terminal measurement.

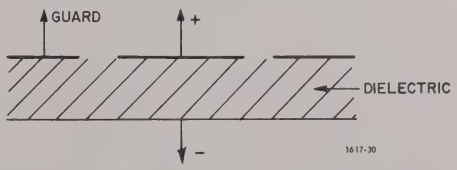


Figure 4-12. Guard-electrode arrangement to measure dielectric samples.

4.5.7 TRANSFORMER INSULATION MEASUREMENT.

The insulation in a transformer, together with the primary and the secondary windings and the transformer case, form a 3-terminal network (Figure 4-13). Usually the three capacitances are of the same order of magnitude, and any one of them can be measured directly by

the bridge, if it is connected between the UNKNOWN terminals and the other two capacitances are connected to the GUARD terminal.

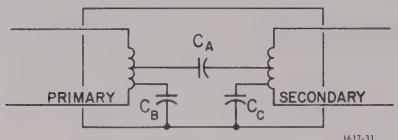


Figure 4-13. Capacitances existing in a transformer.

4.5.8 TEST JIGS.

The Type 1650-P1 Test Jig (refer to the appendix) is available from General Radio for faster measurements, it allows rapid 2- and 3-terminal measurement. Connections to the bridge are made through two Type 274-DB plugs and a clip lead to connect the guard. Special jigs can be made for different shapes of capacitors, or for 4-terminal measurements (paragraph 5.7.3). The principles discussed in paragraph 3.1.4 and 3.1.5 should be taken into account in the design of such a jig.

4.5.9 LIMIT TESTING.

The Type 1617 bridge may be set up to provide a go-no-go indication useful for component testing. The panel meter is used as the indicator. Proceed as follows:

a. Balance the bridge with one of the components to be tested (one within tolerance).

b. Offset the C dial from the balance position by the desired tolerance.

c. Adjust the SENSITIVITY control for a center-scale meter deflection.

d. Set the C dial to the nominal value of the component.

e. Connect each component to the bridge. If the meter deflection is between zero and center scale, the component is within limits.

SECTION 5

PRINCIPLES OF OPERATION

5.1 BRIDGE CIRCUITS.

5.1.1 GENERAL.

The circuit of the Type 1617 Capacitance Bridge is basically the familiar series-capacitance-comparison type used in most general-purpose capacitance bridges. The capacitance, C, of the unknown is proportional to R_N and its dissipation factor, D, to R_S (Figure 5-1).

5.1.2 LOW CAPACITANCE.

On the lowest five capacitance ranges (up to 10 μF), the circuit used is the simple one shown in Figure 5-1; (the guard circuit is connected for 3-terminal measurements). The bridge circuit is oriented so that a grounded dc supply will apply a voltage to the unknown capacitor through the ratio-arm resistor R_A. Reasonable lead resistances and inductances cause negligible errors; for example, a 0.1-Ω lead resistance introduces a D error of less than 0.001 in the measurement of a 10 μF capacitor.

5.1.3 LEAD EFFECTS ON HIGH CAPACITANCE MEASUREMENTS.

One farad is only 1.3 mΩ at 120 Hz and the same 0.1-Ω lead resistance will now result in a D reading of 70.

Figure 5-2 shows R_A and C_X as 4-terminal components; the lead resistances are also drawn and their individual effects can be evaluated. First, r_1 and r_8 are

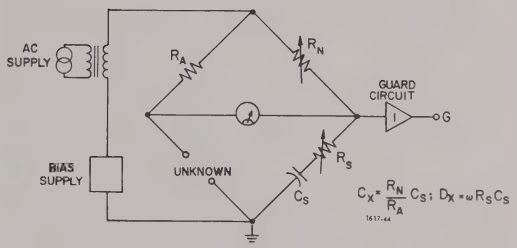


Figure 5-1. The RC bridge used on the five lower capacitance ranges.

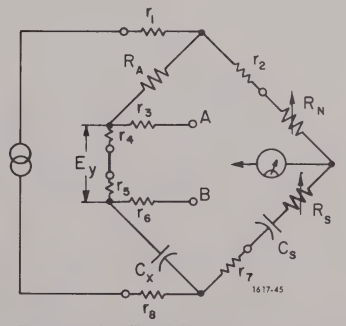


Figure 5-2. The RC bridge circuit where the unknown and the ratio arm resistor are represented as 4-terminal components.

in series with the generator and only reduce the effective applied voltage but do not change the null condition. Then r_2 and r_7 are in series respectively with R_N and R_S-C_S, which have relatively high impedance and, therefore, are little affected; r_3 and r_6 are in series with the detector. The remaining r_4 and r_5 (and their connection) present the main error. Their total impedance may be much higher than the impedance of either C_X or R_A, making the voltage drop across them an important part of the applied voltage.

Tying the detector to point A, places the lead resistance in the C_X arm and introduces an enormous D error; tying it to point B adds the lead resistance to R_A, and the C measurement is erroneous. Moreover, the lead inductance, if placed in series with a very large C_X, would cause a capacitance error even at 120 Hz. Obviously some means of greatly reducing the error is required.

A seemingly natural way to compensate the leads effects would be to divide the voltage from A to B, in the ratio of R_A to the unknown or R_N to the R_S-C_S combination, therefore applying the principle of the Kelvin double bridge (long used for dc resistance measurement) to an ac bridge. This would be done by connecting another pair of arms, similar to the R_N and C_S-R_S arms, from A to B and connecting the detector to the junction of these arms (Figure 5-3).

Corresponding variable components would be ganged to maintain the same ratio in both sets of arms. If the ratios between both pairs of arms were exactly the same, there would be no error, however large the lead impedances might be. Unfortunately, the ability to track with a wirewound rheostat is limited at best by its resolution. In general, tracking to much better than 1% is difficult. When measuring 1 F, 20 mΩ of lead resistance and a tracking accuracy of 1% still produce a C error of over 2%.

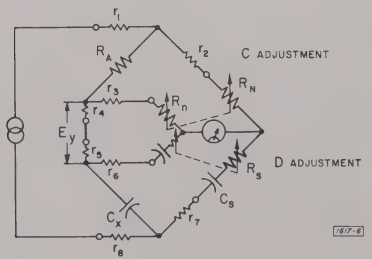


Figure 5-3. A four-terminal capacitance bridge using the Kelvin double-bridge principle. For ac measurement on a complex impedance, two ganged adjustments are necessary.

5.1.4 THE BRIDGE CIRCUIT FOR HIGH CAPACITANCE.

A unique feature of the Type 1617 Capacitance Bridge is the compensation arrangement used to measure high-valued (low-impedance) capacitors, as shown in Figure 5-4.

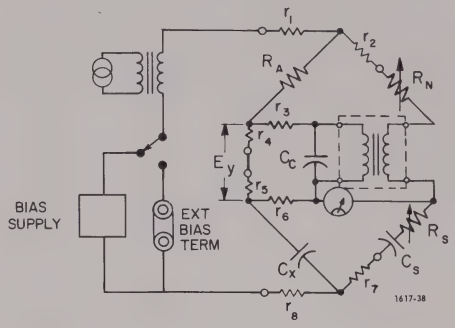


Figure 5-4. The basic circuit of the Type 1617 bridge where a voltage equal to the error voltage, Ey, is placed in the opposite side of the bridge by a tightly coupled transformer.

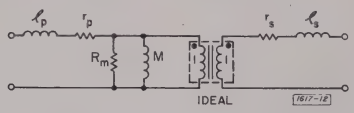


Figure 5-5. Equivalent circuit of the transformer.

The creation of a voltage equal to E_y between the R_N arm and the R_S-C_S arm solves the problem, because the lead error is compensated by the symmetry of the circuit. This is achieved by insertion of a 1:1 transformer. Unfortunately, the transformer, bifilar wound on a high permeability core, is not perfect, as shown by the equivalent circuit of Figure 5-5. C_c is a capacitor placed to "resonate out" some of the effect of the mutual inductance. The coupling coefficient of the transformer differs from unity by only a few parts per million.

The bridge-balance equation yields the following:

$$C_x = \frac{R_N}{R_A} C_S \left[1 + \frac{r_p + r_s + r_3}{R_N} - \frac{(r_4 + r_5)\, l_p}{R_A M} + \frac{(r_4 + r_5)\, r_6 C_X (1 - \omega^2 M C_c)}{M} - \frac{(r_4 + r_5)(r_3 + r_p)}{R_M R_A} - D_x \left(\frac{(r_4 + r_5)(r_3 + r_6)(1 - \omega^2 M C_c)}{R_A \omega M} - \frac{(r_4 + r_5)\, \omega l_p}{R_A R_M} + \frac{\omega (l_p + l_s)}{R_N} \right) \right]$$

This form is quite impracticable, but a little examination will simplify the equation greatly. The first error term is taken into account in the calibration of R_N. By construction, the transformer has very small leakage inductance, making the second, sixth, and seventh terms negligible. The addition of C_c reduces the error in the third and fifth terms. The equation becomes:

$$C_x = \frac{R_N}{R_A} C_S \left\{ 1 + \frac{r_4 + r_5}{R_A} \left[\frac{r_6 C_x (1 - \omega^2 M C_c) R_A}{M} - \frac{r_3 + r_p}{R_M} - \frac{D_x (r_3 + r_6)(1 - \omega^2 M C_C)}{\omega M} \right] \right\}$$

Note that the important error terms are not constant but are functions of the changing R_A and C_X, which makes complete compensation impossible.

The use of this scheme gives extremely good results; measurement of 1F, with $r_4 + r_5 = r_6 = 20\ m\Omega$, gives an error of approximately 0.1%. Therefore, the specification (1% for C) makes allowance for connecting leads of considerable length when large remotely located capacitors are measured.

5.2 GUARD CIRCUIT.

Whenever stray capacitances are an important percentage of the capacitance of the unknown, shielding is necessary to prevent error. The addition of a shield to prevent stray capacitances across the unknown results in an appreciable capacitance created by the shield itself, and a guard point is required to keep these capacitances from affecting the measurement. The guard circuit of the Type 1617 Capacitance Bridge, therefore, advantageously permits remote and 3-terminal measurements (refer to paragraph 3.1.4). It is also useful in that it prevents the internal shields from introducing other stray capacitances.

The junction of the R_N and R_S-C_S arms (point A, Figure 5-6) is usually used as guard point in RC bridges. The capacitance from A to the + UNKNOWN terminal shunts the detector and causes no error. The capacitance from A to ground shunts the R_S-C_S arm but is comparatively so small that it can be neglected. However, the Type 1617 can apply 600 V across the unknown, therefore across the R_S-C_S arm, placing the guard point at a potential of 600 V, a rather undesirable situation.

To avoid this dangerous situation, a unity-gain amplifier is connected between this passive guard point and the actual guard terminal, G, as shown in Figure 5-6. The output of the amplifier is clamped to ground by a rectifier, so that G is never at a high potential,

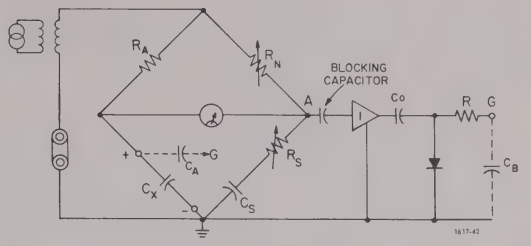


Figure 5-6. The guard circuit with respect to the bridge.

even in case of an accidental short from the guard to the + UNKNOWN terminal.

The performance of the guard circuit is measured by its gain and output impedance. The capacitance from the + UNKNOWN terminal to G (C_A) in effect shunts the unknown, but with a value reduced by a factor of 1-K. The gain, K, of the unity amplifier is approximately 0.999, so that 1000 pF to GUARD is equivalent to approximately 1 pF across C_X. Capacitance from G to ground (C_B) has no effect by itself, but it does reduce the effectiveness of the GUARD because of the limited output impedance of the amplifier. The effective capacitance shunting the unknown is approximately:

$$C_A \left(1 - K \frac{C_o}{C_o + C_B}\right) \approx C_A (1 - K) + \frac{C_A C_B}{C_o}$$

where C_O is the output capacitance of the guard circuit (10 μF).

The resistor in series with the guard protects the grounding rectifier from excessive current and has a lower impedance than the 10 μF output capacitor at 120 Hz.

A shorted GUARD terminal does not damage the guard circuit, but impairs the accuracy of the bridge.

5.3 THE INTERNAL GENERATOR.

The generator can be considered a selective filter operating on the rectified line voltage, or an oscillator synchronized to the line. The former is probably more accurate because the circuit would not oscillate when powered by a supply having low ripple.

The filter circuit is a simple Wien-bridge feedback arrangement, with two arms formed by the RC-Wien network, and the other two by the level-adjustment divider. The line voltage is full-wave rectified, to supply a signal rich in the 120-Hz component, and the filter capacitor is purposefully small so that a great amount of this signal reaches the input stage by means of the bias resistor (R217).

The compound (Darlington) output stage drives the primary of the input transformer at a level of about 5 V, rms. This transformer isolates the generator circuit from the capacitance bridge, which may have 600 Vdc

applied to it. It also provides several output voltages by means of secondary taps selected by the GEN LEVEL switch.

5.4 INTERNAL DETECTOR.

The detector for this bridge is ungrounded and yet powered by the line, even though the bridge signal is a line harmonic. This makes the limitation of hum pickup both critical and difficult. Extensive shielding and guarding, both in the transformer and the leads, keeps the pickup negligible and controls the stray capacitances to ground.

The detector circuit is a straight-forward selective-amplifier circuit. The input stage has a high input impedance to avoid loading the bridge on the lower ranges (when it presents a very high impedance to the detector). The selective stage is made "flat" by ungrounding the twin-T selective circuit, when the function switch is in the EXT GEN position. The output stages form an amplifier capable of high compression, accomplished by a diode network in the feedback voltage divider. This compression gives a "semi-logarithmic" characteristic to the meter response, allowing balances over a wide dynamic range without repeated adjustments of the DETECTOR SENSITIVITY potentiometer (R443). No connection to the detector output is available on the panel of the Type 1617 Capacitance Bridge because it is very rarely necessary. However, the use of a shielded transformer (GR Type 578-A or -B) connected to the detector board (Figure 5-7) will make this output readily usable if it is required.

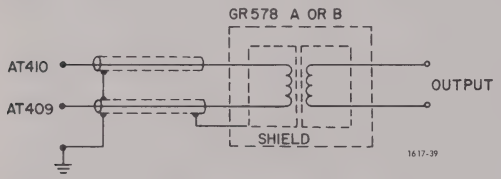


Figure 5-7. Connections to the detector etched board to make the detector output available.

5.5 THE BIAS VOLTAGE SUPPLY.

The bias-voltage supply is connected in series with the input transformer and bridge as shown in Figure 5-8, so that the full dc is applied to the capacitor being measured. The ac signal is applied to the bridge in series with the dc supply, which therefore must present a low ac impedance at its output to avoid a serious reduction of the ac voltage applied to the bridge when large capacitors are measured. This requirement is met by placing a capacitor at the output of the dc supply to present a low impedance to the ac signal. This capacitor must be able to charge to the full bias voltage. A different capacitor, offering the lowest impedance at the required voltage, is switched in as the bias voltage range is changed (giving optimum conditions at all times).

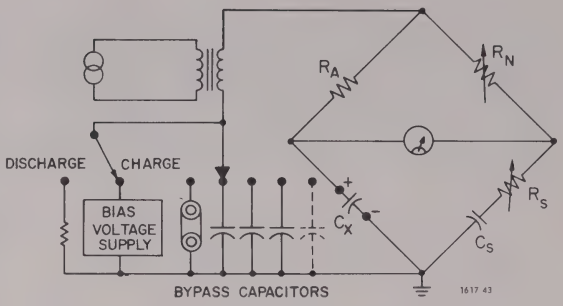


Figure 5-8. The bias-voltage supply and its battery of bypass capacitors.

The high-voltage supply itself is a series-regulator circuit, using a high-voltage vacumm tube as the series element and transistors for additional loop gain. The supply is adjustable both continuously and in steps. The continuous adjustment is accomplished with an adjustable reference sampled by one side of the differential input stage. The other input samples the voltage across a fixed resistor in series with the switched range resistors.

On the 2-V range, the sampling resistor (R214) is tied directly to ground and the adjustment span is set for 2 V, maximum, by means of R208. Thus, 1 mA flows in the sampling resistor for a full-scale setting. This condition is still met when resistors are placed between the sampling resistor and ground, making the maximum output voltage (in volts) for each range equal to the value of the total resistance (in kilohms) added, plus 2 V.

It should be noted that all the regulator circuitry may be off ground by the full bias voltage and, therefore, the bias should be set to a low voltage range when this circuit is to be serviced.

5.6 ORTHONULL.®

Orthonull is a mechanical device that improves the bridge balance convergence when high-D capacitors are measured. Ordinarily, balances with such components are tedious and often impossible, due to the "sliding null" resulting from the interdependence of the two adjustments. Rapid balances are possible with Orthonull, which does not affect the electrical balance conditions but which does help avoid false nulls, improving bridge accuracy for high-D measurements. The unbalance voltage of the bridge, that is the voltage existing across the detector before balance is achieved, can be expressed as follows:

$$E_O = E_{in}\frac{Z_2Z_4 - Z_1Z_3}{(Z_1 + Z_2)(Z_3 + Z_4)} = E_{in}\frac{Z_2 - \frac{Z_1Z_3}{Z_4}}{(Z_1 + Z_2)\left(1 + \frac{Z_3}{Z_4}\right)}$$

where Z_1, Z_2, Z_3, Z_4 are the impedances of the four arms.

For the bridge of Figure 5-1:

$$E_O = \frac{R_X + \frac{1}{j\omega C_X} - \frac{R_A R_S}{R_N} + \frac{1}{j\omega C_S R_N}}{\text{Denominator}}$$

We will assume that the denominator is more or less constant in the region of the null. The numerator is the difference between the unknown impedance $R_X + \frac{1}{j\omega C_X}$ and what can be called the "bridge impedance". The bridge output is proportional to this difference, which is the distance between them on the complete plane. To balance the bridge, the bridge impedance is varied by adjustment of R_N (the C dial) and R_S (the D dial), until it equals the unknown impedance. An adjustment of R_S varies only the real part of the bridge impedance, whereas the adjustment of R_N varies both parts, and is therefore a multiplier of the bridge impedance. Thus, adjustment of R_S moves the bridge impedance horizontally on the complex plane, while adjustment of R_N moves it radially (see Figure 5-9). Each control is adjusted for a minimum voltage.

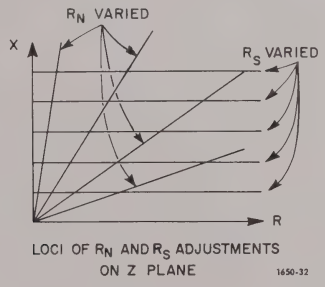


Figure 5-9. Loci of R_n and R_s adjustments on the Z plane.

When X≫R (i.e., when D is low) these two adjustments are almost orthogonal, and rapid convergence is possible. When D is high, however, the adjustment becomes more parallel and convergence is slow, causing a "sliding null", as shown in Figure 5-10, where D = 2. With higher D's, convergence is even slower.

The Orthonull device makes the two adjustments orthogonal by nonreciprocally ganging R_N and R_S. From the equation, it is apparent that if R_S/R_N remained constant as R_N was varied, only the imaginary part of the bridge impedance would change. But when

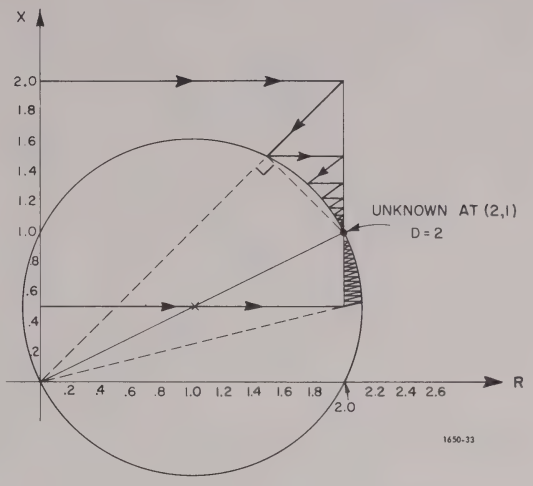


Figure 5-10. Loci of "sliding null" balances.

R_S is adjusted, R_N must not move, to vary only the real part. The solution is a simple friction clutch to permit nonreciprocal action. Both the inherent difference in friction of the two rheostats and the pulley ratio favor torque transmission is the desired direction.

The ratio R_S/R_N must be constant for variation in R_N for any initial settings of R_N and R_S, since R_S may be moved independently of R_N. This requires rheostats with exponential characteristics (and logarithmic dials). The D rheostat is a 54-dB exponential potentiometer. The C rheostat is exponential in the dial range from 1 to 11, and linear below 1. Thus, for correct Orthonull action, the C dial must always be set in the range above 1.

The advantage of Orthonull is illustrated in Figure 5-11, which is a plot of the number of adjustments necessary for a balance. Not only does the Orthonull reduce the number of balances, but it permits 1% measurements that would otherwise be impossible with D above 3, due to the finite resolution of the D rheostat. This finite resolution causes the meter indication to vary in jumps when Orthonull is used at D's above 3. However, by selection of the best null, 1% accuracy is possible with D's of more than 5 and 20% with D's of 10.

5.7 THREE-AND-FOUR-TERMINAL MEASUREMENTS.

5.7.1 GENERAL.

Stray impedances - the plague of precise metrology - are of two kinds: shunt and series impedances. Fortunately, in the case of capacitance measurements, they are rarely both important at the same time. The

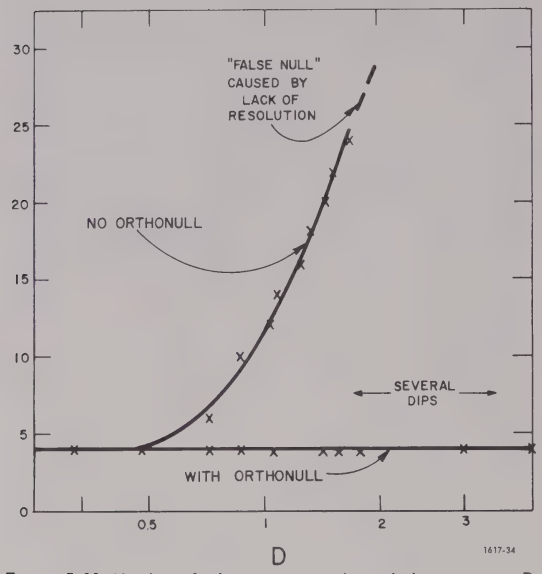


Figure 5-11. Number of adjustments to obtain balance versus D.

shunt impedances introduce error in low-capacitance measurements and are corrected by 3-terminal measurements. The series impedances are important in the measurement of high capacitance (low impedance) and necessitate 4-terminal measurements.

5.7.2 THREE-TERMINAL MEASUREMENTS.

The shielding of a low-valued capacitor prevents the direct shunting of the unknown by a stray capacitance. However, the shield is, in effect, a third terminal and there may be appreciable capacitance from the terminals of the unknown to the shield (Figure 5-12).

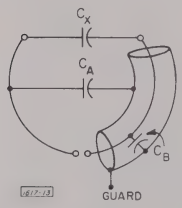


Figure 5-12. Measurement of a capacitor Cx with a shielded lead and the resulting stray capacitances. The shield prevents stray capacitance from being set up directly across the unknown.

The object is to eliminate C_A and C_B from the direct measurements of C_X. This can be accomplished by measurement of short-circuit transfer admittance, $\frac{I_o}{E_{in}}$, of the circuit of Figure 5-13.

If the source and the ammeter have zero impedance, the measurement is independent of C_A and C_B and:

$$y_{21} = I_o/E_{in} = j\omega C_x$$

The Type 1617 Capacitance Bridge uses an active guard circuit to achieve the same result (refer to paragraph 5.2).

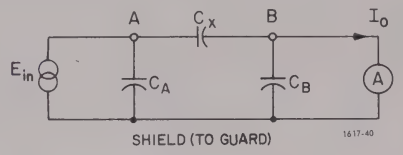


Figure 5-13. Elimination of the effect of the stray capacitances C_A and C_B by a short-circuit transfer-admittance measurement.

5.7.3 FOUR-TERMINAL MEASUREMENTS.

A high-valued capacitor is little affected by a shunt stray capacitance but, because of its low impedance, it is very much affected by a series stray impedance (such as lead resistance). Here, a measurement of transfer impedance, $\frac{E_o}{I_{in}}$, will eliminate the effect of the leads (Figure 5-14) if both the source and the voltmeter have infinite impedances; $\frac{E_o}{I_{in}} = Z_{21}$ is exactly the impedance from A to A_1, i.e., $\frac{1}{j\omega C_x}$. This method shows quite clearly why in a 4-terminal component, two terminals (C, C') are usually labelled the "current" terminals and two, (P, P') the "potential" terminals.

The Type 1617 uses a similar, if not exactly identical method of measurement. Its two outer connectors can be considered "current terminals" and the inner connectors "potential terminals".

It is interesting to note that there are some applications where both series and shunt stray impedances affect the unknown enough to require that both 3- and 4-terminal techniques be used at the same time. Examples are: very high precision measurements on standard capacitors of medium value, [1] high-frequency measurements on capacitors and measurements on remotely located components (refer to paragraph 4.5.1).

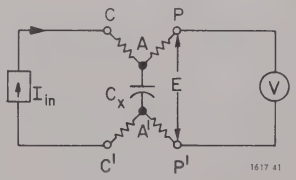


Figure 5-14. Elimination of the lead impedance by a transfer-impedance measurement.

[1] R.D. Cutkosky, "Four Terminal Pair Networks as Precision Pair Networks," IEEE Transactions on Communication and Electronics, #70, January 1962, page 19.

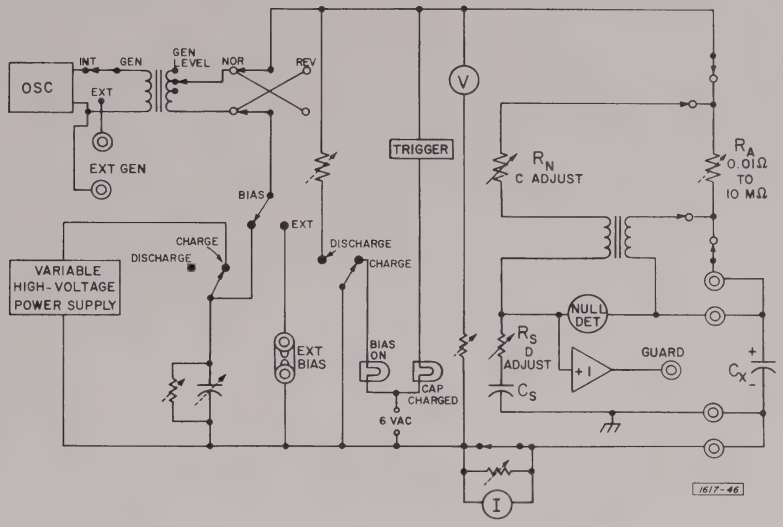


Figure 5-15. Simplified schematic of Type 1617 Capacitance Bridge showing three measurement modes: null, voltage, and current.

5.8 GENERAL.

The interrelationship of the several circuits that make up the Type 1617 Capacitance Bridge will become more apparent by reference to Figure 5-15, a simplified schematic description of the complete instrument. Comprehensive circuit details are presented in the full schematic drawings shown in Section 6.

SECTION 6

SERVICE AND MAINTENANCE

6.1 WARRANTY.

We warrant that each new instrument manufactured and sold by us is free from defects in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards, after examination by our factory, District Office, or authorized repair agency personnel, will be repaired, or at our option, replaced without charge, except for tubes or batteries that have given normal service.

6.2 SERVICE.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest District Office, requesting a "Returned Material Tag". Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

6.3 TROUBLE ANALYSIS.

6.3.1 PRELIMINARY CHECKS.

If satisfactory balances are difficult or impossible to obtain, make the following external checks first.

1. Is the instrument connected to the line?
2. Is the power on?
3. Is the unknown connected correctly?
4. Are all the panel controls set properly?
5. Are all the shorting links in place? For 2- and 3-terminal measurements, link the two positive terminals and link the two negative terminals. The link on the EXT BIAS terminals should always be connected if the terminals are not in use.
6. Is the unknown what it is thought to be? Try measuring a known component.
7. Is the D so high that Orthonull should be used?
8. Is the SENSITIVITY control on?

6.3.2 TROUBLE ANALYSIS.

The Type 1617 Capacitance Bridge is self-contained and incorporates six major circuits, the generator, the detector, the guard and trigger, the bias supply, the meter and the bridge; one or several of these may become defective.

A component is connected and balance is attempted.

1. NOISY OR ERRATIC BALANCE. This may be due to surface contamination of the wirewound C and D control rheostats. Contamination can form if the bridge is left idle for an extended period and can be eliminated by rotating the controls several times.

2. WRONG VOLTAGE INDICATION.

If the bias was applied and it appears that a wrong result is obtained, a d-c voltmeter across the unknown will read the actual value of the dc bias applied. If this is not what was intended, or shown by the meter, the internal supply is faulty, proceed to paragraph 6.4.3 (see also paragraph 3.4).

3. CAPACITANCE MEASUREMENT ERROR. If the measurement was guarded (3-terminal) and it appears that the guard does not accomplish its purpose, proceed to paragraph 6.4.4. The proper functioning of the guard when measuring a small capacitor (<0.01 μF) is checked by connecting a capacitor (around 1000 pF) from the guard to the positive terminal. If the reading is not appreciably changed, the guard is operative. Loss of proper guard action can cause errors in the highest as well as the lowest C ranges. Check guard if error appears on those ranges (see above).

Finally, if the balance obtained is known to be erroneous, some bridge circuit component is faulty, (refer to paragraph 6.4.6).

4. NO DEFLECTION. A process of elimination will localize the trouble.

a. Connect an external generator (120 Hz giving 5 V, rms); the Types 1310 or 1311 oscillators are well suited for the purpose. If balance is obtainable, the internal generator is faulty (refer to paragraph 6.4.1). If nothing happens, proceed below.

b. Detector and Meter Check – Keep the external generator connected and set controls as follows:

MULTIPLIER switch to 100 pF.
C Dial to 10.
D Dial to 1.
GEN LEVEL MAX VOLTS to 0.2.
DETECTOR SENSITIVITY fully clockwise.

c. Disconnect the link at the two positive UNKNOWN terminals, thus isolating the detector input and connect an oscillator between AT401* and AT402. A signal from this oscillator of approximately 0.5 V at 120 Hz should drive the meter full scale. This meter should peak at 120 Hz ±2%.

If the check is negative, either the detector or the meter is faulty. Connect an external indicator (earphones, scope . . .) to the detector output (refer to paragraph 5.4 and Figure 5-7) and again look for this signal. If it is there, the meter is faulty; if it is not the detector is to be repaired. Proceed to paragraph 6.4.2.

*The anchor terminals (AT) are the most accessible test points, they are on one side of the etched boards (see Figures 6-7 through 6-9). The AT is usually omitted on the board All anchor terminals with the same first digit (4 in AT401) are on the same board.

5. EXCESSIVE DISCHARGE TIME. On the high-voltage ranges, high-capacitance ranges, and combinations of high capacitance/high voltage, where lethal charges may be present at the UNKNOWN terminals, the circuit is designed so as to discharge the capacitor being measured very quickly. Therefore, when the BIAS CHARGE-DISCHARGE control is switched to DISCHARGE, the CAPACITOR CHARGED lamp should go out almost immediately.

When measuring high-value capacitors at low voltage, it may take up to several seconds to drop the bias voltage below 1 volt and therefore have the lamp go out, but this is not a dangerous condition.

If the time required for discharge is excessive, it may indicate a burned-out discharge resistor (R178 through R181), or a faulty discharge switch (S106).

6.4 DETAIL TROUBLE ANALYSIS (Figure 6-1).

6.4.1 GENERATOR.

Set the function switch to INT 120 C, the MULTIPLIER switch to 1 μF, and connect a scope across R115 (on switch S102). The waveform (120 Hz) should be free of distortion and have an amplitude equal to the setting of the GEN LEVEL MAX VOLTS switch (S105). If the level is incorrect adjust R222. (Too high a level causes waveform distortion). If some, but not all three, voltages are obtained, check switch S105 for proper contact and check the secondary taps of T101 for open-circuit indications. If the correct ac output cannot be obtained, check the dc levels within the generator circuit (Table 6-6) and the ac voltages at transformer output T501 (Table 6-1).

Table 6-1

Transformer Secondary Voltages (T501) With 115 V Into The Primary (Figures 6-2 and 6-10)

Pins	*Voltage (rms)*
5-6	9.6 V
7-8	4.8 V
8-9	15.3 V
10-11	110 V
11-12	155 V
13-14	110 V
14-15	6.0 V
17-18	15.0 V

6.4.2 DETECTOR.

With 0.5 mV applied (paragraph 6.3.2), Table 6-2 shows typical waveforms and amplitudes. Check the dc voltages as in Table 6-6.

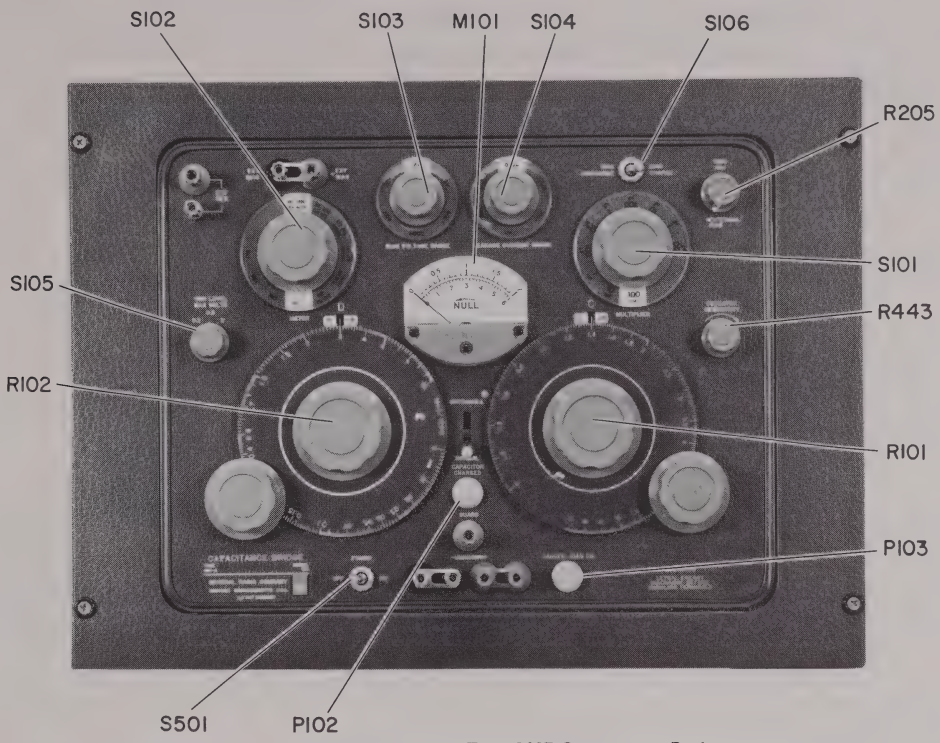
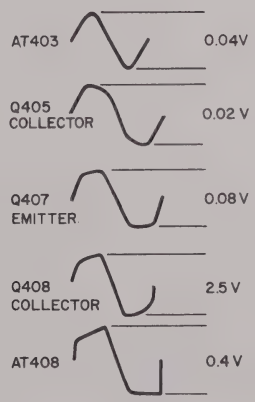


Figure 6-1. Front view of the Type 1617 Capacitance Bridge.

Table 6-2

Waveforms in the Detector Circuit (Figure 6-2)

AT403	~0.04 V
Coll., Q405	~0.02 V
Emitt., Q407	~0.8 V
Coll., Q408	~2.5 V
AT408	~0.4 V



6.4.3. INTERNAL BIAS SUPPLY.

To check the internal bias supply:

a. If the measured voltage is correct on all ranges but the indication of the Type 1617 meter differs from the measured value –

Adjust R183 (VOLTAGE RANGE switch on 2V).

Check the meter-range resistors (R158 through R163) for proper value (on second deck of S103).

b. If the measured voltage is wrong on only some ranges, check the values of the resistors of the first deck of S103 and the switch contacts associated with these resistors.

c. The highest voltage in each range is not equal to the value indicated on the switch legend – adjust R208. If not sufficient, check all dc levels as in Table 6-6.

d. If the dc bias voltage varies with line voltage, check the 7239 tube and the transistors of the circuit (Table 6-6).

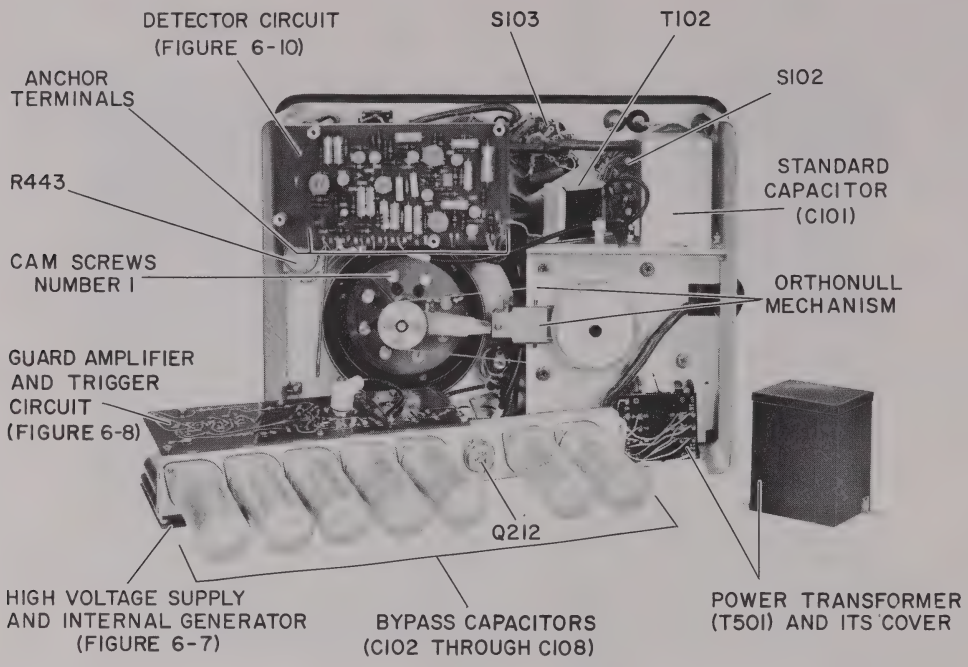


Figure 6-2. Rear interior view of the Type 1617 Capacitance Bridge.

6.4.4 GUARD CIRCUIT.

Observe that:

a. The shield around the positive UNKNOWN terminals, and all the shielded cables from UNKNOWN and GUARD terminals are properly guarded.

b. The lead connecting the unknown to the positive terminal is properly shielded.

c. The guard-circuit amplifier is functioning. To do this, set the function switch to INT 120C, the MULTIPLIER switch to 1 μF, the C dial to 0, and switch the bias off. Then the ac voltage measured between the GUARD terminal and ground should be the same as that measured from the positive unknown terminal to ground.

A negative check is caused by a faulty amplifier or some shorted guard point. To find out if the amplifier is operating, check the guard output at AT307, with the white-yellow-brown lead disconnected. If the amplifier is not functioning properly check the dc voltages in Table 6-6.

6.4.5 TRIGGER.

The trigger circuit should operate so that it fires the CAPACITOR CHARGED lamp when a bias of 0.5 to 1.0 volt is applied to the UNKNOWN TERMINALS. Check the dc voltages if it does not (Table 6-6).

6.4.6 BRIDGE.

For an unknown $(R_x + \frac{1}{\omega C_x})$, the balance equations of the bridge are:

$$R_x = \frac{R_A}{R_N} R_S \text{ and } C_x = \frac{R_N}{R_A} C_S$$

where R_A and C_S are fixed components.

R_N and R_S are rheostats (C and D dials) and all four components have to be within tolerance.

Check the calibration of the bridge by making the measurements of Table 6-3. Six standard capacitors are shown although any range can be checked using any capacitor of known value which falls within that range. Suitable capacitors include the Type 1409 Standard Capacitor, Type 1423-A Precision Decade Capacitor, and Type 1424-A and 1425-A Standard Decade Capacitors.

If large standard capacitors are not available, the higher capacitance ranges may be checked by direct measurement of the ratio-arm resistors, for these are the only components in the bridge that change with the range. These resistors (R103 through R112) may be measured with a dc bridge. A Kelvin, four-terminal bridge is necessary for the two highest ranges, and preferable for the next two lower ones, to avoid errors due to lead resistance.

Table 6-3

Bridge Calibration Check

Measurement	*Standard Value*	*Connection No Terminals*	*MULTIPLIER setting*	*C setting ±1%*	*Faulty R_A*
a	100 pF	3*	100 pF	1	R112
b	10 MF	3	1 nF	10	R111
c	10 nF	3	10 nF	1	R110
d	1 μF	3	100 nF	10	R109
e	1 μF	3	1 μF	1	R108
f	100 μF	4**	10 μF	10	R107
g	100 μF	4	100 μF	1	R106
h	100 μF	4	1 mF	0.1	R105
i	10 mF	4	1 mF	10	R105
j	10 mF	4	10 mF	1	R104
k	100 mF	4	100 mF	1	R103

*three-terminal measurement (two-lead cable)
**four-terminal measurement (three-lead cable).

The main circuit diagram, Figure 6-13, indicates the terminals on S101 that should be used for connection. (The highest capacitance range uses the lowest-valued resistors e.g., R103.) The four highest ranges use a four-terminal connection in the bridge. Each resistor should be within 0.25% of its nominal value. The range switch should be set to a range other than that being measured to avoid error. The side pan of the instrument will have to be removed for access to the higher-value units.

The results of the measurements in Table 6-3 indicate:

1. When only one measurement is in error the corresponding faulty component is listed in Table 6-3.

2. When all measurements at either 1 or 10 on the C dial are in error, the C rheostat is in error at 1 or 10.

3. When all measurements are in error by the same percentage (value), the standard capacitor (C101) is faulty.

4. When measurements are in error by the same arc of displacement, whether at 0.1 or 10 on the C dial (measurement f and h), the dial has slipped and is easily realigned.

5. When all measurements and all fixed components of the bridge are within tolerance, if the C rheostat is correct on the 1 and 10 setting, it may still be incorrect between 1 and 10 (refer to paragraph 6.5.2).

6.5 CALIBRATION PROCEDURE.

The few internal adjustments are factory set and normally do not require readjustment. Procedures for recalibration are included here but should be used only when the operator is reasonably certain that it is necessary.

6.5.1 GENERAL.

An impedance bridge with an accuracy of 0.25% or better is necessary; the Type 1608 Impedance Bridge can be used.

If the trouble is narrowed to the ratio arm resistors (R_A) or the standard capacitor, ascertain that they are within tolerances (±0.25% for R_A, ±0.25% for C_S); change any defective unit.

The C rheostat can be recalibrated (paragraph 6.5.3); the D rheostat is fixed and only slipping of the dial can be corrected (paragraph 6.5.3); finally the orthonull operation can be checked (paragraph 6.5.4).

6.5.2 C CALIBRATION.

If it has been found that the C rheostat is faulty, it can be readjusted by means of its justifying mechanism. Two methods can be used to do so.

Direct Resistance Measurement. The C rheostat mechanical justifying mechanism consists of eight cam screws located on the rear of the C rheostat (see Figure 6-2), numbered from 1 to 8 in a clockwise direction from the slit on the cam plate. They can be adjusted by setting them for the proper resistances as indicated in Table 6-4. To reach the rheostat, remove two screws on each side of the inner plates, unsolder the connecting wire, and swing down the battery of capacitors.

NOTE

If these cam screws seem to be completely out of adjustment, preset cam screw 1 four turns from fully clockwise and preset the remaining screws two turns from fully clockwise, before attempting the adjustment procedure.

Table 6-4

C Dial Calibration Adjustments (Figure 6-2)

Dial Reading	*Resistance* Ohms*	*Tolerance*	*Adjust Cam Screw*
0.1	200	190 to 210 ±1/4 division	1
0.6	1,200	1190 to 1210 ±1/4 division	2
1.3	2,600	2574 to 2626 (±1/2%)	3
2.2	4,400	4356 to 4444 (±1/2%)	4
3.6	7,200	7128 to 7272 (±1/2%)	5
5.5	11,000	10,890 to 11,110 (±1/2%)	6
8.0	16,000	15,840 to 16,160 (±1/2%)	7
11.0	22,000	21,780 to 22,220 (±1/2%)	8

**Use decade resistor (GR 1433-M or equivalent).*

If, after adjustment, the cam plate is too high or too low, reposition the C dial on its shaft and repeat the cam-screw adjustment procedure.

Adjustment From A Measurement. A somewhat easier method (because it does not require a resistance bridge) consists in connecting a variable capacitor (like the GR 1423 or 1426 Precision Capacitors) to the bridge, and making the balance setting of the C dial and the known value of C, agree by adjustment of the proper cam screw.

Proceed as follows:

a. Connect the variable standard of value S to the bridge UNKNOWN TERMINALS.

b. Set the MULTIPLIER on (M) and the C Dial on (C), so as to have S =(M) x (C)

c. Balance the bridge with the D dial and the cam screw (s) closest to the rheostat arm.

d. Change S and C and repeat the procedure until all cam screws are adjusted.

NOTE

It is advantageous to choose the settings of the C dial given in Table 6-4, because the cam screw to be adjusted is then directly under the rheostat arm.

Slow-Motion Knob. If the C slow-motion knob slips or is inoperative, either the large disk behind the C dial is not riding properly in the grooved disk behind the vernier knob, or there is insufficient friction between the two disks.

Loosen the nut under the small knob and move it away from the large knob to reset the two disks, or move it closer to the large knob to increase friction.

6.5.3 D DIAL CHECK.

To check the calibration of the D dial proceed as follows:

a. Set the MULTIPLIER switch to 100 nF.

b. Set the C dial on 5.

c. Connect to the bridge a 0.5 μF Standard Capacitor*, such as GR 1409 in series with a decade resistance box, such as a GR 1433 (Figure 6-3).

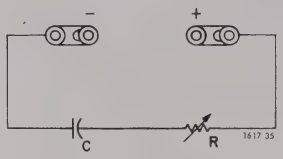


Figure 6-3. Connections for R and C in the D-dial check.

d. Set the resistance according to Table 6-5 and observe that the bridge balances for the corresponding D setting.

If the first and last measurements are in error by the same arc or displacement of the dial, then the dial has slipped. If the errors are random, the rheostat is faulty (it cannot be adjusted and has to be changed).

Table 6-5

D Checks C = .5 μF

Resistance Setting	*D* Setting*
268 Ω	0.1
2.68 KΩ	1
8.1 KΩ	3
13.4 KΩ	5
26.8 KΩ	10

* ± specified accuracy ± .001 ±.01 C (in F) ±2%.

6.5.4 ORTHONULL OPERATION.

With the lever in the NORMAL position, the C and D dials must operate independently of each other.

With the lever in the ORTHONULL position, the C dial must move the D dial but the D dial must not move the C dial; if performance is different and ——

*Actually any combination of C and R can be used. D = ωRC has to check with the D setting (within specifications).

1. D dial moves C dial:

ORTHONULL lever-spring tension is excessive. Turn the nut on the spade-lug counterclockwise to reduce tension.

2. C dial doesn't move D dial:

a. ORTHONULL lever-spring tension is insufficient. Turn the nut on the spade-lug clockwise to increase tension.

b. Lever spring is broken or otherwise defective.

c. Drive cable between C dial and D dial is broken or off the pulley.

Replace the ORTHONULL drive cable as follows (see Figure 6-4):

a. Insert the cable ends through slots 1 and 2 of the D pulley and attach the eyelets to the springs.

NOTE

The cable is attached only to the D pulley at this time.

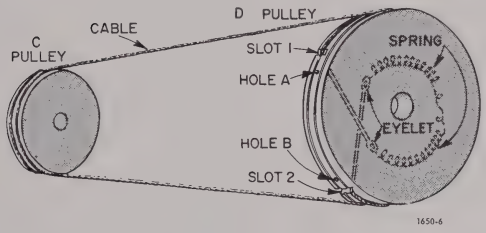


Figure 6-4. Replacement of the Orthonull drive cable.

b. Pull the cable until the eyelets are visible through holes A and B. Insert a pin or small nail through the holes into the respective cable eyelet and release the cable. The pins hold the springs expanded to allow the cable to be threaded around the C pulley.

c. Set the C dial to 1.8. Thread the cable from slot 1, around the D pully in the groove nearest the panel and then around the C dial in the second groove from the panel.

d. Continue the cable around the C pulley until it emerges from the third groove from the panel and return it to the D dial.

e. The cable is now completely threaded and the pins can be removed from holes A and B.

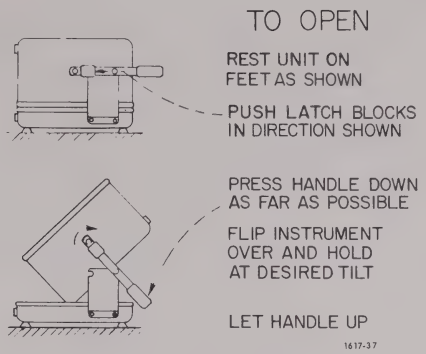

TO OPEN
REST UNIT ON FEET AS SHOWN
PUSH LATCH BLOCKS IN DIRECTION SHOWN
PRESS HANDLE DOWN AS FAR AS POSSIBLE
FLIP INSTRUMENT OVER AND HOLD AT DESIRED TILT
LET HANDLE UP
1617-37

Figure 6-5. Operation of the flip-tilt cabinet.

6.6 FLIP-TILT CABINET.

Figure 6-5 shows the operation of the flip-tilt cabinet and Figure 6-6 shows details of the pivoting part of the flip-tilt.

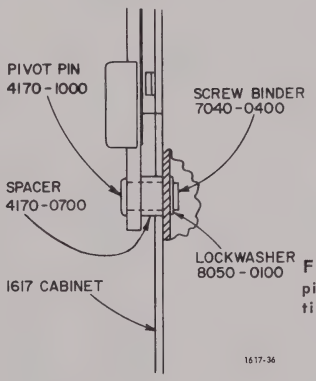


Figure 6-6. Details of the pivot assembly of the flip-tilt cabinet.

6.7 REPAIR AND REPLACEMENT.

Defective parts indicated by the trouble-analysis procedures should be repaired or replaced. As an aid in the location of detail parts on the bridge, the etched-circuit boards used are shown in Figures 6-7, 6-8 and 6-10. Figures 6-9, 6-11 and 6-13 contain the complete wiring schematic drawings for the instrument. Figure 6-12 is a switch wiring diagram for front-panel controls.

Reference designators used in all the figures are the same as those used in the parts list that follows.

Table 6-6
DC Voltages

Test Conditions:

GEN LEVEL MAX VOLTS = 0.5
INT. 120 C GEN NORM
BIAS VOLTAGE RANGE = 2 V
LEAKAGE CURRENT RANGE = 60 μA
BIAS CHARGE switch on
BIAS ADJ control fully CW
DETECTOR SENS control fully CCW
MULTIPLIER = 1 μF
C DIAL = 0
D DIAL = 0
J101 tied to J102, J103 tied to J104

All voltages to chassis ground unless otherwise stated.

High Voltage Supply (Figures 6-7 and 6-9)

V201
Pin #1 -5.80 V
Pin #2 2.35 V
Pin #6 92.0 V
AT205 2V
AT205 to AT206 2V on all ranges

	Emitter	*Collector*
Q201	-11.0 V	-5.80 V
Q202	0.645 V	-11.0 V
Q203	0.645 V	-10.5 V

AT207	0.007 V	AT211	-18.2
AT208	0.007 V	AT301	142 V
AT209	-15.5	AT303	142 V
AT210	-15.5	AT304	300 V

Generator (Figures 6-7 and 6-9)

	Emitter	*Collector*
Q204	1.20 V	8.35 V
Q205	8.50 V	0.910 V
Q212	8.70 V	0.910 V

AT201	4.5 V	AT203	0.62 V
AT202	4.5 V	AT204	-0.003

Guard Amplifier (Figures 6-8 and 6-9)

	Emitter	*Collector*
Q301	8.75 V	12.7 V
Q302	12.7 V	17.8 V
Q303	18.2 V	8.95 V

Positive side of C307 18.2
AT310 2 V
AT305 0 V

Trigger (Figures 6-8 and 6-9)

	Emitter	*Collector*
Q304	0 V	0.025 V
Q305	0.480 V	0 V
Q306	0.830 V	0 V

AT306 -1.9 V
AT307 -0.25 V
AT308 -0.007 V

Detector (Figures 6-10 and 6-11)

All transistor voltages are to detector low (AT402)

	Emitter	*Collector*
Q401	0.250 V	3.60 V
Q402	3.00 V	7.80 V
Q403	7.60 V	13.3 V
Q404	5.85 V	13.2 V
Q405	13.3 V	10.0 V
Q406	10.1 V	6.40 V
Q407	5.70 V	12.6 V
Q408	12.7 V	6.10 V
Q409	19.0 V	15.7 V
Q410	9.35 V	18.8 V

AT401 through AT405	1.9 V
AT407	1.9 V
AT408	2 V
AT409	1.9 V
AT410	1.4 V
AT411, 412	-0.28 V
positive side of C407	15.9 V

6.8 MINIMUM PERFORMANCE STANDARDS.

The following procedure for checking the capacitance and dissipation-factor measurement accuracy of the 1617 bridge is recommended for incoming inspection or periodic operational testing.

6.8.1 EQUIPMENT REQUIRED.

The specifications in Table 6-7 are minimum requirements. Equivalent equipment may be substituted for the recommended models.

6.8.2 CAPACITANCE.

To check the bridge for capacitance measurement accuracy, proceed as follows:

a. Connect the adjustable standard to the bridge. Refer to paragraph 3.1 for correct procedure recommended to obtain optimum results.

NOTE

The GR 1423 is recommended for capacitance values of 100pF to 1μF; the GR 1426 is suitable for capacitance values of 10μF to 1F.

b. Measure the capacitance standard at various settings (refer to paragraph 3.2) and compare results with accuracy specifications. Seven to ten measurements between 100pF and 1μF, and the seven values available between 1μF and 1F on the 1426, should be adequate for most performance tests.

6.8.3 DISSIPATION FACTOR.

To check the bridge for dissipation factor measurement accuracy, proceed as follows:

a. Connect the Precision Decade Resistor (GR 1433-K) and a 0.5μF standard capacitor (GR 1423) to the bridge as shown in Figure 6-3.

b. Compare the calibration of the D dial with the D accuracy specifications. Refer to paragraph 6.5.3 and Table 6-5 for instructions.

6.9 KNOB REMOVAL.

If it should be necessary to remove the knob on a front-panel control, either to replace one that has been damaged or to replace the associated control, proceed as follows:

a. Grasp the knob firmly with the fingers and pull the knob straight away from the panel.

CAUTION

Do not pull on the dial to remove a dial/knob assembly. Always remove the knob first.

b. Observe the position of the set screw in the bushing, with respect to any panel marking (or at the full ccw position of a continuous control).

c. Release the set screw and pull the bushing off the shaft.

Table 6-7

Type	*Description*	*Recommendation*
Precision Decade Capacitor	Range: 100pF to 1μF, in 100pF steps. Accuracy: ±0.05% over entire range. Connections available: 2 and 3 terminal.	GR 1423-A
Capacitance Standard	Range: 1μF to 1F, in seven or more steps that adequately cover the entire range. Accuracy: ±0.25%, lower values; ±1% for 1F. Connections available: 2, 3, and 4 terminal.	GR 1426
Precision Decade Resistor	Range: 25Ω to 300Ω, in 1Ω steps. Accuracy: ±0.02% over entire range. Connections available: 2 and 3 terminal.	GR 1433-M
Connector Leads	Four-terminal cable assembly, supplied with the 1617 bridge. Additional double-plug and single-plug patch cords as required. All leads should be as short as possible.	Refer to Appendix

d. Remove and retain the black Nylon thrust washer, behind the dial/knob assembly, as appropriate.

NOTE

To separate the bushing from the knob, if for any reason they should be combined off the instrument, drive a machine tap a turn or two into the bushing for a sufficient grip for easy separation.

6.10 KNOB INSTALLATION.

To install a knob assembly on the control shaft:

a. Place the black Nylon thrust washer over the control shaft, if appropriate.

b. Mount the bushing on the shaft, using a small slotted piece of wrapping paper as a shim for adequate panel clearance.

c. Orient the set screw on the bushing with respect to the panel-marking index and lock the set screw.

NOTE

Make sure that the end of the shaft does not protrude through the bushing or the knob won't set properly.

d. Place the knob on the bushing with the retention spring opposite the set screw.

e. Push the knob in until it bottoms and pull it slightly to check that the retention spring is seated in in the groove in the bushing.

NOTE

If the retention spring in the knob comes loose, reinstall it in the interior notch with the small slit in the outer wall.

PARTS LIST for 200 and 300 series only

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
CAPACITORS					
C201	Electrolytic, 16μF +100-10% 150 V	4450-0200	37942	D33104	5910-931-7064
C202	Ceramic, 0.1μF ±20% 50 V	4403-4100	80131	CC63, 0.1μF ±20%	
C203	Ceramic, 0.001μF +80-20% 500 V	4404-2109	72982	831, 0.001μF +80-20%	
C204	For 60-Hz operation: Plastic, 0.1μF ±2% 100 V	4860-8251	84411	663uW, 0.1μF ±2%	
	For 50-Hz operation: Plastic, 0.121μF ±2% 100 V	4860-7908	84411	663uW, 0.121μF ±2%	
C205	For 60-Hz operation: Plastic, 0.1μF ±2% 100 V	4860-8251	84411	663uW, 0.1μF ±2%	
	For 50-Hz operation: Plastic, 0.121μF ±2% 100 V	4860-7908	84411	663uW, 0.121μF ±2%	
C206	Electrolytic, 40μF +100-10% 6 V	4450-3600	37942	20-40707S4	5910-952-0467
C207	Electrolytic, 100μF +100-10% 25 V	4450-2300	76149	20-40595	5910-799-9284
C208	Electrolytic, 100μF +100-10% 25 V	4450-2300	76149	20-40595	5910-799-9284
C301	Electrolytic, 4μF +100-10% 475 V	4450-2000	80183	D32845	5910-893-0879
C302	Electrolytic, 4μF +100-10% 475 V	4450-2000	80183	D32845	5910-893-0879
C303	Plastic, 0.22μF ±10% 400 V	4860-9501	84411	663uW, 0.22μF ±10%	
C304	Electrolytic, 40μF +100-10% 6 V	4450-3600	37942	20-40707S4	5910-952-0467
C305	Electrolytic, 15μF +100-10% 15 V	4450-3700	37942	TT, 15μF +100-10%	
C306	Ceramic, 0.0047μF +80-20% 500 V	4405-2479	72982	801, 0.0047μF +80-20%	
C307	Electrolytic, 40μF +100-10% 6 V	4450-3600	37942	20-40707S4	5910-952-0467
C308	Electrolytic, 60μF +100-10% 25 V	4450-2900	56289	D17872	5910-799-9280
C309	Electrolytic, 60μF +100-10% 25 V	4450-2900	56289	D17872	5910-799-9280
C310	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C312	Ceramic, 0.047μF +80-20% 250 V	4409-3479	72982	3851, 0.047μF +80-20%	
DIODES					
CR201	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR202	Type 1N645	6082-1016	24446	1N645	5961-944-8222
CR203	Type 1N976B	6083-1020	86800	1N976B	5960-854-8469
CR204	Type 1N967B	6083-1016	28959	1N967B	
CR205	Type 1N957B	6083-1009	07910	1N957B	
CR206 thru CR210	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR211	Type 1N976B	6083-1020	86800	1N976B	5960-854-8469
CR301 thru CR304	Type 1N3256	6081-1004	12672	1N3256	5960-972-9395
CR305	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR306	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR307	Type 1N645	6082-1016	24446	1N645	5961-944-8222
CR308	Type 1N645	6082-1016	24446	1N645	5961-944-8222
CR309	Type 1N645	6082-1016	24446	1N645	5961-944-8222
RESISTORS					
R201	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R202	Composition, 470kΩ ±5% 1/2 W	6100-4475	01121	RC20GF474J	5905-279-2515
R203	Composition, 150Ω ±5% 1/2 W	6100-1155	01121	RC20GF151J	5905-299-1541
R204	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R205	Potentiometer, Composition, 5kΩ ±10%	6040-1955	01121	J, 5kΩ ±10%	
R206	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R207	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R208	Potentiometer, wire-wound, 5kΩ ±10%	6051-2509	80294	3007P-1-502	
R209	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R210	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R211	Composition, 120kΩ ±5% 1/2 W	6100-4125	01121	RC20GF124J	5905-192-3981
R212	Composition, 20kΩ ±5% 1/2 W	6100-3205	01121	RC20GF203J	5905-192-0649
R213	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R214	Film, 2kΩ ±1% 1/8 W	6250-1200	75042	CEA, 2kΩ ±1%	5905-577-6614
R216	Film, 13kΩ ±1% 1/8 W	6250-2130	75042	CEA, 13kΩ ±1%	5905-892-6924
R217	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R218	Film, 15.8kΩ ±1% 1/8 W	6250-2158	75042	CEA, 15.8kΩ ±1%	5905-810-4997
R219	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R220	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R221	Composition, 2kΩ ±5% 1/2 W	6100-2205	01121	RC20GF202J	5905-190-8887
R222	Potentiometer, wire-wound, 1kΩ ±10%	6051-2109	96791	2600PC, 1kΩ ±10%	
R223	Composition, 3kΩ ±5% 1/2 W	6100-2305	01121	RC20GF302J	5905-279-1751

PARTS LIST for 200 and 300 series only (cont)

Ref. Desig.	*Description*	*GR Part No.*	*FMC*	*Mfg. Part No.*	*Fed. Stock No.*
RESISTORS (Cont)					
R224	Composition, 470Ω ±5% 1/2 W	6100-1475	01121	RC20GF471J	5905-192-3973
R225	Wire-wound, 0.47Ω ±10% 2 W	6760-8479	75042	BWH, 0.47Ω ±10%	
R301	Composition, 220kΩ ±5% 1/2 W	6100-4225	01121	RC20GF224J	5905-192-0667
R302	Composition, 150kΩ ±5% 1/2 W	6100-4155	01121	RC20GF154J	5905-279-2522
R303	Composition, 47kΩ ±5% 1/2 W	6100-3475	01121	RC20GF473J	5905-254-9201
R304	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R305	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R306	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R307	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R308	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R309	Composition, 1MΩ ±5% 1/2 W	6100-5105	01121	RC20GF105J	5905-192-0390
R310	Composition, 330kΩ ±5% 1/2 W	6100-4335	01121	RC20GF334J	5905-279-2519
R311	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R312	Wire-wound, 1Ω ±10% 2 W	6760-9109	75042	BWH, 1Ω ±10%	
R313	Wire-wound, 100Ω ±5% 5 W	6660-1105	80183	246E, 100Ω ±5%	
R314	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R315	Composition, 1MΩ ±10% 1 W	6110-5109	01121	GB, 1MΩ ±10%	
R316	Composition, 1MΩ ±10% 1 W	6110-5109	01121	GB, 1MΩ ±10%	
R317	Composition, 100Ω ±5% 1/2 W	6100-1105	01121	RC20GF101J	5905-190-8889
R318	Composition, 2kΩ ±5% 1/2 W	6100-2205	01121	RC20GF202J	5905-190-8887
TRANSISTORS					
Q201	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q202	Type 2N3702	8210-1106	01295	2N3702	
Q203	Type 2N3702	8210-1106	01295	2N3702	
Q204	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800
Q205	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q212	Type 2N1544	8210-1014	75491	2N1544	
Q301	Type 2N2414	8210-1047	24446	2N2414	5961-989-2749
Q302	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q303	Type 2N3702	8210-1106	01295	2N3702	
Q304	Type 2N910	8210-1037	24454	2N910	
Q305	Type 2N3702	8210-1106	01295	2N3702	
Q306	Type 2N3702	8210-1106	01295	2N3702	
MISCELLANEOUS					
V201	Tube	8380-7239	24446	7239	5960-060-7592

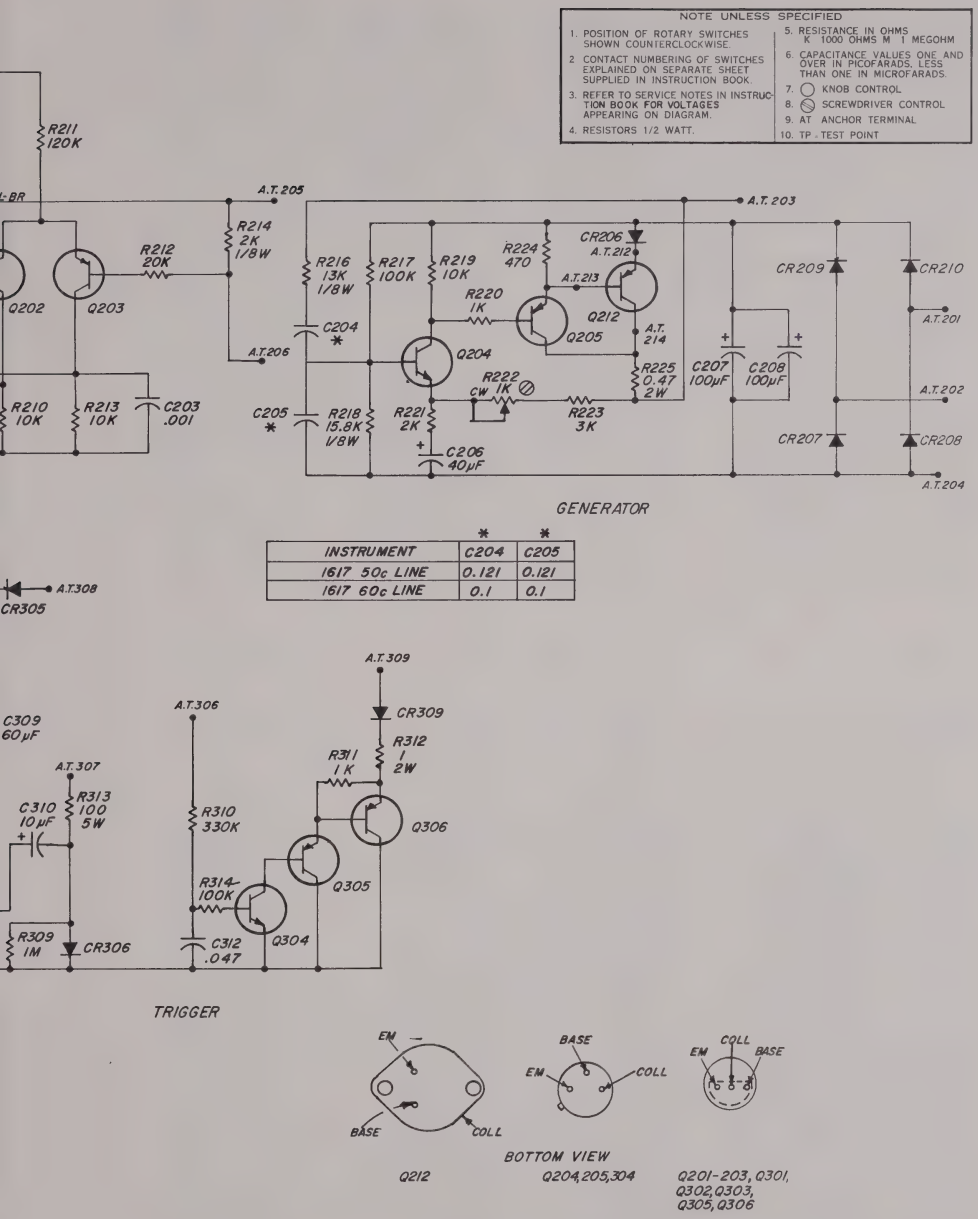


Figure 6-9. Schematic diagram of the high-voltage supply, guard, trigger and generator circuits.

PARTS LIST for 200 and 300 series only (cont)

Ref. Desig.	*Description*	*GR Part No.*	*FMC*	*Mfg. Part No.*	*Fed. Stock No.*
RESISTORS (Cont)					
R224	Composition, 470Ω ±5% 1/2 W	6100-1475	01121	RC20GF471J	5905-192-3973
R225	Wire-wound, 0.47Ω ±10% 2 W	6760-8479	75042	BWH, 0.47Ω ±10%	
R301	Composition, 220kΩ ±5% 1/2 W	6100-4225	01121	RC20GF224J	5905-192-0667
R302	Composition, 150kΩ ±5% 1/2 W	6100-4155	01121	RC20GF154J	5905-279-2522
R303	Composition, 47kΩ ±5% 1/2 W	6100-3475	01121	RC20GF473J	5905-254-9201
R304	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R305	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R306	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R307	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R308	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R309	Composition, 1MΩ ±5% 1/2 W	6100-5105	01121	RC20GF105J	5905-192-0390
R310	Composition, 330kΩ ±5% 1/2 W	6100-4335	01121	RC20GF334J	5905-279-2519
R311	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R312	Wire-wound, 1Ω ±10% 2 W	6760-9109	75042	BWH, 1Ω ±10%	
R313	Wire-wound, 100Ω ±5% 5 W	6660-1105	80183	246E, 100Ω ±5%	
R314	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R315	Composition, 1MΩ ±10% 1 W	6110-5109	01121	GB, 1MΩ ±10%	
R316	Composition, 1MΩ ±10% 1 W	6110-5109	01121	GB, 1MΩ ±10%	
R317	Composition, 100Ω ±5% 1/2 W	6100-1105	01121	RC20GF101J	5905-190-8889
R318	Composition, 2kΩ ±5% 1/2 W	6100-2205	01121	RC20GF202J	5905-190-8887
TRANSISTORS					
Q201	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q202	Type 2N3702	8210-1106	01295	2N3702	
Q203	Type 2N3702	8210-1106	01295	2N3702	
Q204	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800
Q205	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q212	Type 2N1544	8210-1014	75491	2N1544	
Q301	Type 2N2414	8210-1047	24446	2N2414	5961-989-2749
Q302	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q303	Type 2N3702	8210-1106	01295	2N3702	
Q304	Type 2N910	8210-1037	24454	2N910	
Q305	Type 2N3702	8210-1106	01295	2N3702	
Q306	Type 2N3702	8210-1106	01295	2N3702	
MISCELLANEOUS					
V201	Tube	8380-7239	24446	7239	5960-060-7592

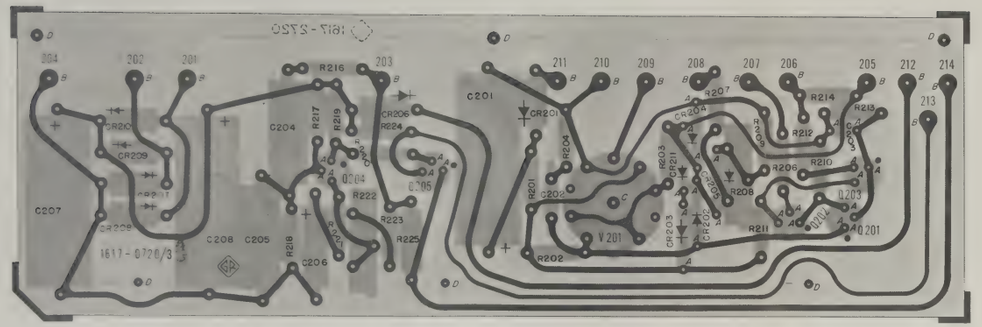


Figure 6-7. The high-voltage supply and the generator etched board (P/N 1617-2780).

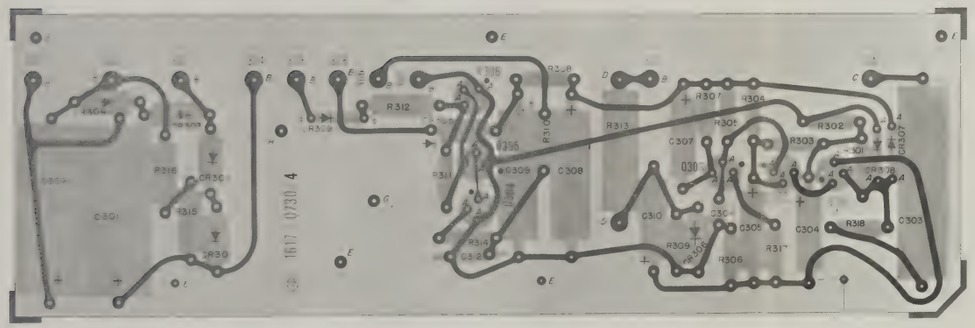


Figure 6-8. The guard amplifier and trigger etched board (P/N 1617-2730).

NOTE: The number on the foil side is not the part number for the complete assembly. The dot on the foil at the transistor socket indicates the collector lead.

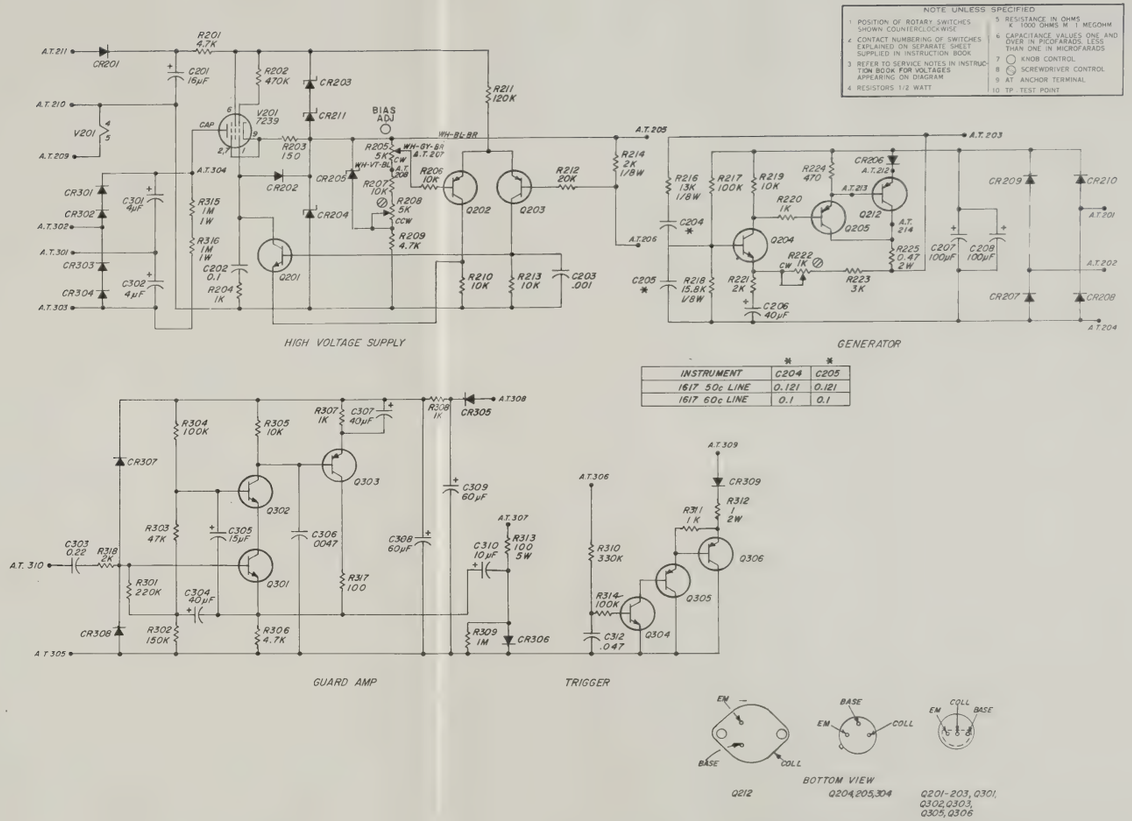
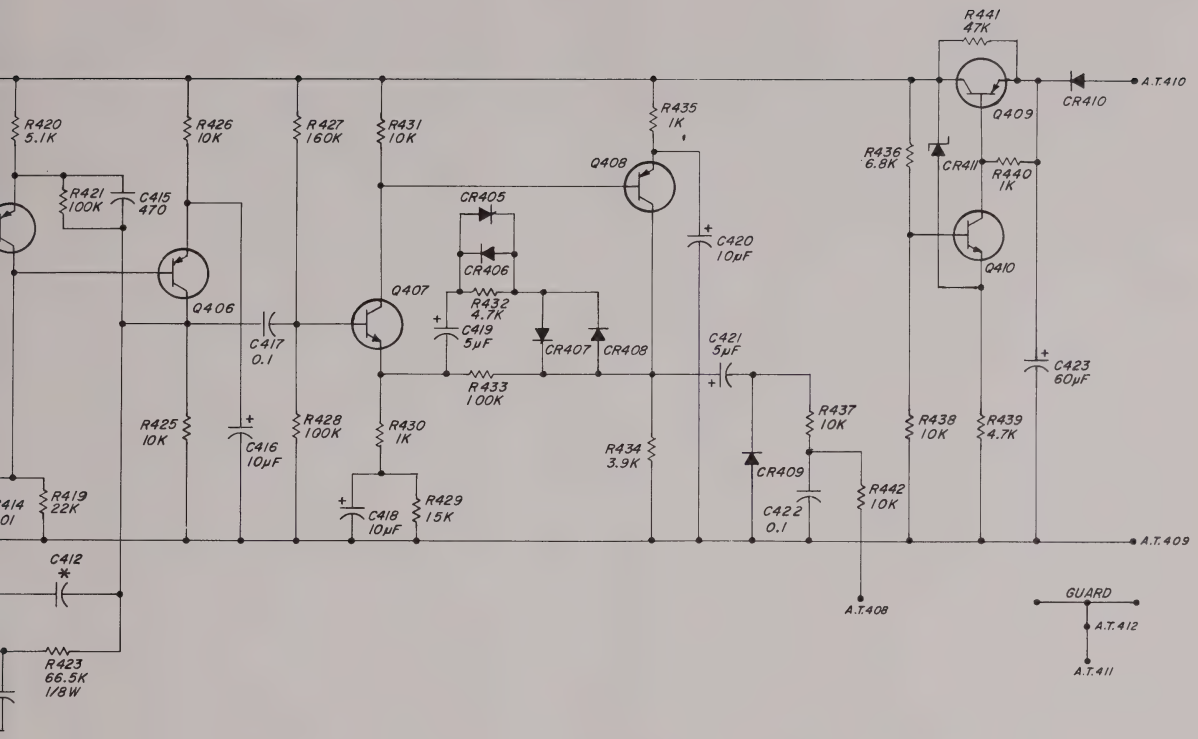

NOTE UNLESS SPECIFIED
1 POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE
4 CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK
3 REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM
4 RESISTORS 1/2 WATT
5 RESISTANCE IN OHMS K 1000 OHMS M 1 MEGOHM
6 CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS
7 KNOB CONTROL
8 SCREWDRIVER CONTROL
9 AT ANCHOR TERMINAL
10 TP TEST POINT
HIGH VOLTAGE SUPPLY
GENERATOR
GUARD AMP
TRIGGER
INSTRUMENT | C204 | C205
1617 50c LINE | 0.121 | 0.121
1617 60c LINE | 0.1 | 0.1
BOTTOM VIEW
Q212
Q204,205,304
Q201-203, Q301, Q302,Q303, Q305,Q306

Figure 6-9. Schematic diagram of the high-voltage supply, guard, trigger and generator circuits.



INSTRUMENT	C411 *	C412 *	C413 *
1617 50c LINE	.0243	.0243	.0475
1617 60c LINE	.02	.02	.04

Figure 6-11. Schematic diagram for the detector circuit.

PARTS LIST for 400 series only

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
CAPACITORS					
C401	Ceramic, 0.01μF +80-20% 500 V	4406-3109	72982	811, 0.01μF +80-20%	5910-977-7579
C402	Ceramic, 0.1μF +80-20% 50 V	4403-4100	80131	CC63, 0.1μF +80-20%	5910-811-4788
C403	Ceramic, 470pF ±10% 500 V	4404-1478	72982	831, 470pF ±10%	
C404	Electrolytic, 5μF +100-10% 50 V	4450-3900	37942	2040595S9C10x3	5910-448-5527
C405	Electrolytic, 5μF +100-10% 50 V	4450-3900	37942	2040595S9C10x3	5910-448-5527
C406	Electrolytic, 5μF +100-10% 50 V	4450-3900	37942	2040595S9C10x3	5910-448-5527
C407	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C408	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C409	Ceramic, 0.22μF +80-20% 12 V	4432-4229	56289	29C365, 0.22μF +80-20%	
C410	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C411	For 60-Hz operation: Plastic, 0.02μF ±1% 100 V	4860-7853	84411	663uW, 0.02μF ±1%	
	For 50-Hz operation: Plastic, 0.0243μF ±1% 100 V	4860-7833	84411	663uW, 0.0243μF ±1%	
C412	For 60-Hz operation: Plastic, 0.02μF ±1% 100 V	4860-7853	84411	663uW, 0.02μF ±1%	
	For 50-Hz operation: Plastic, 0.0243μF ±1% 100 V	4860-7833	84411	663uW, 0.0243μF ±1%	
C413	For 60-Hz operation: Plastic, 0.04μF ±1% 100 V	4860-7836	84411	663uW, 0.04μF ±1%	
	For 50-Hz operation: Plastic, 0.0475μF ±1% 100 V	4860-8204	84411	663uW, 0.0475μF ±1%	
C414	Ceramic, 0.01μF +80-20% 50 V	4401-3100	80131	CC61, 0.01μF +80-20%	5910-974-5697
C415	Ceramic, 470pF ±10% 500 V	4404-1478	72982	831, 470pF ±10%	
C416	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C417	Ceramic, 0.1μF +80-20% 50 V	4403-4100	80131	CC63, 0.1μF +80-20%	5910-811-4788
C418	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C419	Electrolytic, 5μF +100-10% 50 V	4450-3900	37942	2040595S9C10x3	5910-448-5527
C420	Electrolytic, 10μF +100-10% 25 V	4450-3800	56289	30D106G025BB4M1	5910-952-8658
C421	Electrolytic, 5μF +100-10% 50 V	4450-3900	37942	2040595S9C10x3	5910-448-5527
C422	Ceramic, 0.1μF +80-20% 50 V	4403-4100	80131	CC63, 0.1μF +80-20%	5910-811-4788
C423	Electrolytic, 60μF +100-10% 25 V	4450-2900	56289	D17872	5910-799-9280
DIODES					
CR401	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR402 thru CR408	Type 1N645	6082-1016	24446	1N645	5961-944-8222
CR409	Type 1N191	6082-1008	93916	1N191	5961-296-3360
CR410	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
CR411	Type 1N957B	6083-1009	07910	1N957B	
RESISTORS					
R403	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R404	Composition, 1MΩ ±5% 1/2 W	6100-5105	01121	RC20GF105J	5905-192-0390
R405	Composition, 22MΩ ±5% 1/2 W	6100-6225	01121	RC20GF226J	5905-259-2990
R406	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R407	Composition, 62kΩ ±5% 1/2 W	6100-3625	01121	RC20GF623J	5905-249-3656
R408	Composition, 30kΩ ±5% 1/2 W	6100-3305	01121	RC20GF303J	5905-192-3978
R409	Composition, 3kΩ ±5% 1/2 W	6100-2305	01121	RC20GF302J	5905-279-1751
R410	Composition, 470Ω ±5% 1/2 W	6100-1475	01121	RC20GF471J	5905-192-3973
R411	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R412	Composition, 470Ω ±5% 1/2 W	6100-1475	01121	RC20GF471J	5905-192-3973
R413	Composition, 2kΩ ±5% 1/2 W	6100-2205	01121	RC20GF202J	5905-190-8887
R414	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R415	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R416	Composition, 4.3kΩ ±5% 1/2 W	6100-2435	01121	RC20GF432J	5905-257-0935
R417	Composition, 16kΩ ±5% 1/2 W	6100-3165	01121	RC20GF163J	5905-279-3501
R418	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R419	Composition, 22kΩ ±5% 1/2 W	6100-3225	01121	RC20GF223J	5905-171-2004
R420	Composition, 5.1kΩ ±5% 1/2 W	6100-2515	01121	RC20GF512J	5905-279-2019
R421	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R422	Film, 66.5kΩ ±1% 1/8 W	6250-2665	75042	CEA, 66.5kΩ ±1%	5905-726-5323
R423	Film, 66.5kΩ ±1% 1/8 W	6250-2665	75042	CEA, 66.5kΩ ±1%	5905-726-5323
R424	Film, 33.2kΩ ±1% 1/8 W	6250-2332	75042	CEA, 33.2kΩ ±1%	5905-681-8758
R425	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R426	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R427	Composition, 160kΩ ±5% 1/2 W	6100-4165	01121	RC20GF164J	5905-279-1871
R428	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R429	Composition, 15kΩ ±5% 1/2 W	6100-3155	01121	RC20GF153J	5905-279-2616
R430	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R431	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510

PARTS LIST for 400 series only (cont)

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
RESISTORS (Cont)					
R432	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R433	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761
R434	Composition, 3.9kΩ ±5% 1/2 W	6100-2395	01121	RC20GF392J	5905-279-3505
R435	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R436	Composition, 6.8kΩ ±5% 1/2 W	6100-2685	01121	RC20GF682J	5905-279-3503
R437	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R438	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R439	Composition, 4.7kΩ ±5% 1/2 W	6100-2475	01121	RC20GF472J	5905-279-3504
R440	Composition, 1kΩ ±5% 1/2 W	6100-2105	01121	RC20GF102J	5905-195-6806
R441	Composition, 47kΩ ±5% 1/2 W	6100-3475	01121	RC20GF473J	5905-254-9201
R442	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R443	Potentiometer, Composition, 50kΩ ±10%	6020-0600	01121	JA, 50kΩ ±10%	5905-539-4900
TRANSISTORS					
Q401	Type 2N929	8210-1002	01295	2N929	5960-226-8578
Q402	Type 2N3414	8210-1047	24446	2N3414	5961-989-2749
Q403	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800
Q404	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800
Q405	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q406	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q407	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800
Q408	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q409	Type 2N1305	8210-1305	96214	2N1305	5961-853-1079
Q410	Type 2N1304	8210-1304	01295	2N1304	5961-892-0800

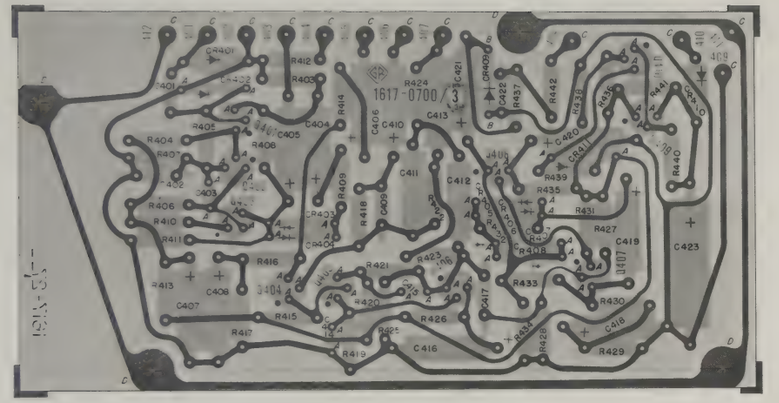


Figure 6-10. The detector etched board (P/N 1617-2770).

NOTE: The number on the foil side is not the part number for the complete assembly. The dot on the foil at the transistor socket indicates the collector lead.

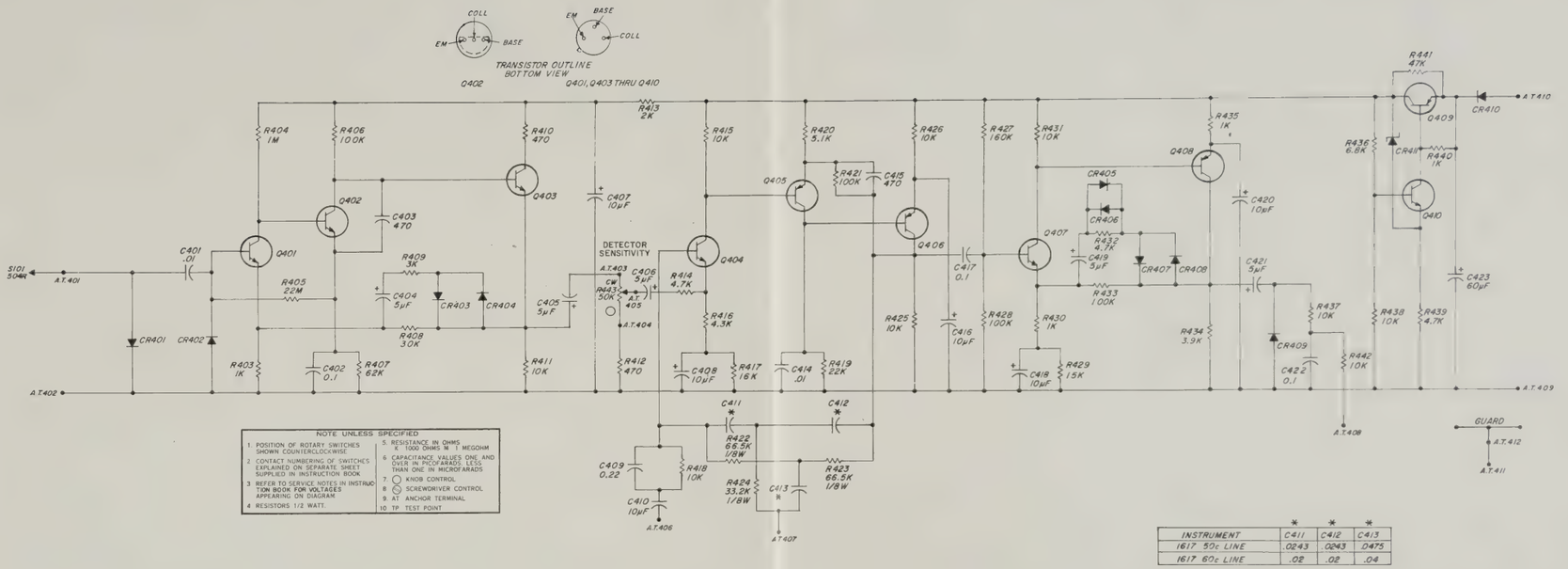
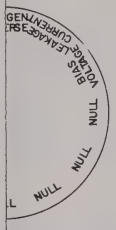


Figure 6-11. Schematic diagram for the detector circuit.



FOR 60c LINE)

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

EV
LTS
2

EGEND

m for Type 1617 front panel controls.

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

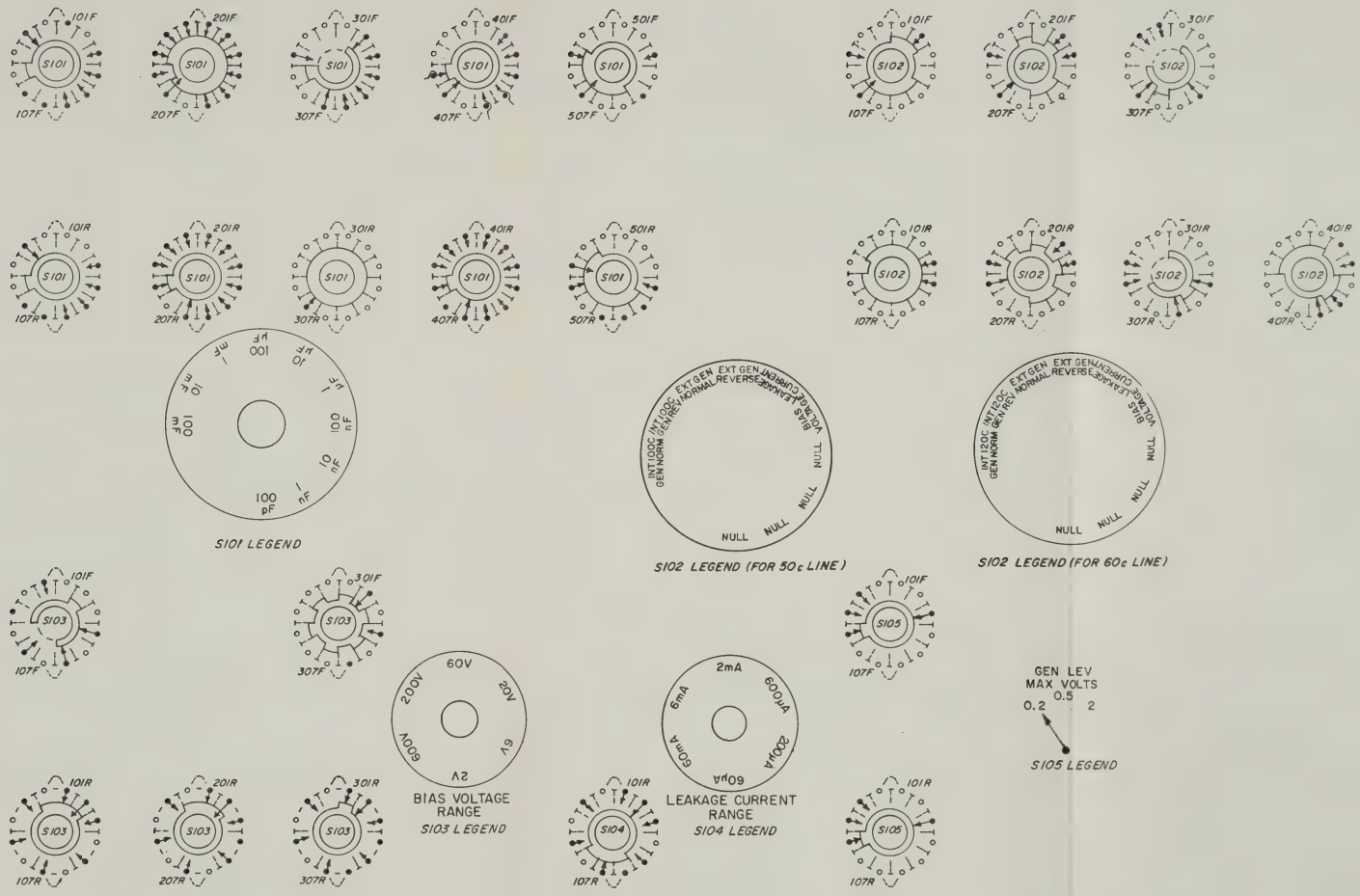
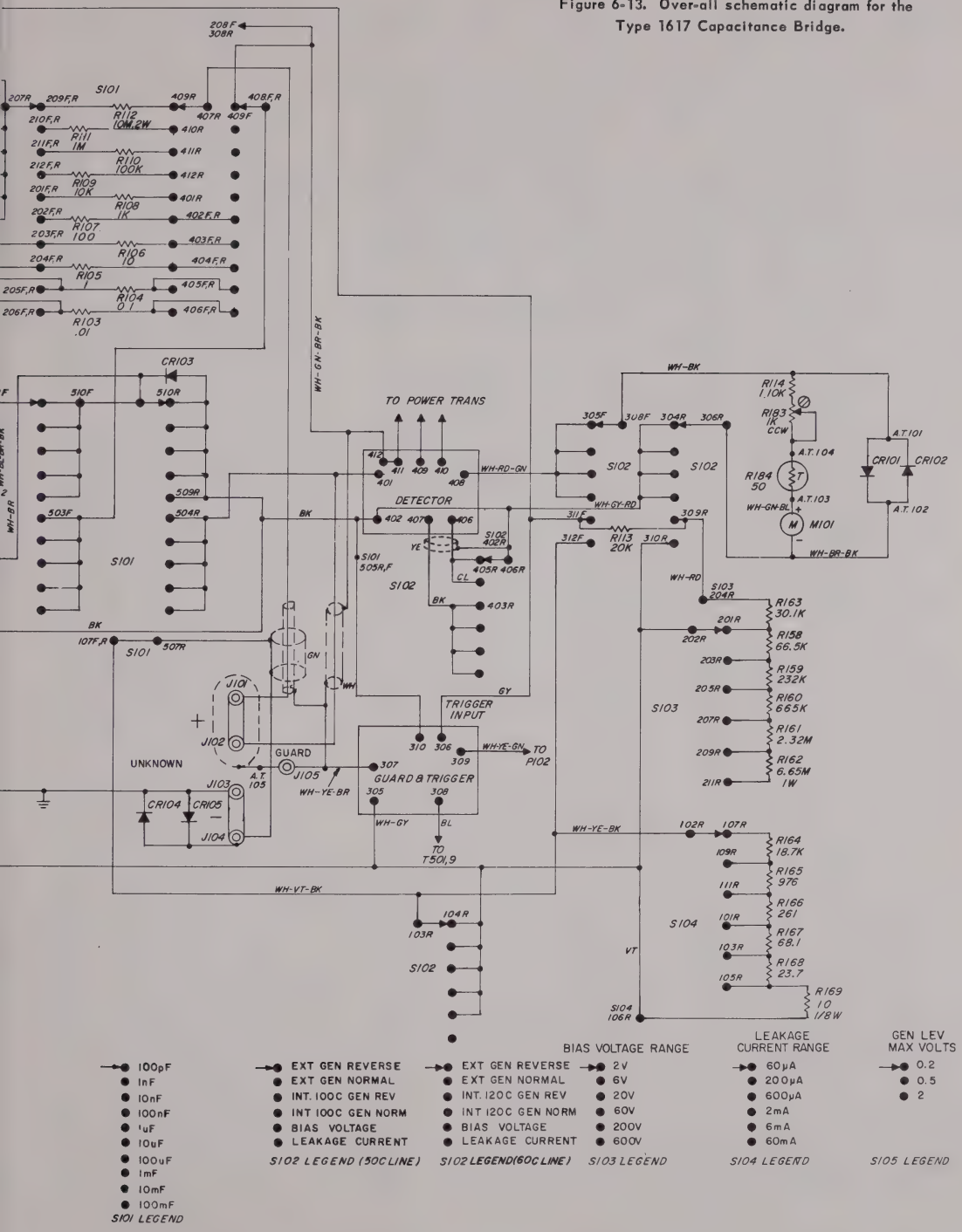


Figure 6-12. Switch diagram for Type 1617 front panel controls.

PARTS LIST for 100 and 500 series only (cont)

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
RESISTORS (Cont)					
R175	Composition, 300kΩ ±5% 1/2 W	6100-4305	01121	RC20GF304J	5905-185-6859
R176	Composition, 470kΩ ±5% 1/2 W	6100-4475	01121	RC20GF474J	5905-279-2515
R177	Composition, 470kΩ ±5% 1/2 W	6100-4475	01121	RC20GF474J	5905-279-2515
R178	Wire-wound, 0.47Ω ±10% 5 W	6660-9047	75042	AS-5, 0.47Ω ±10%	
R179	Wire-wound, 1.8Ω ±5% 5 W	6660-9185	75042	AS-5, 1.8Ω ±5%	
R180	Wire-wound, 22Ω ±5% 5 W	6660-0225	80183	246E, 22Ω ±5%	5905-448-5687
R181	Wire-wound, 200Ω ±5% 5 W	6660-1205	80183	246E, 200Ω ±5%	
R183	Potentiometer, wire-wound, 1kΩ ±10%	6050-1300	12697	43, 1kΩ ±10%	
R184	Thermistor, 50Ω ±10%	6740-1900	02606	CB15L1	
R187	Wire-wound, 4.7Ω ±10% 2 W	6760-9479	75042	BWH, 220Ω ±10% 2 W	
R188	Wire-wound, 220Ω ±10% 2 W	6760-1229	75042	AS-10, 3kΩ ±5%	
SWITCHES					
S101	Rotary, 10 position, 5 section	7890-3790	24655	7890-3790	
S102	Rotary, 6 position, 4 section	7890-3800	24655	7890-3800	
S103	Rotary, 6 position, 3 section	7890-3810	24655	7890-3810	
S104	Rotary, 6 position, 1 section	7890-3820	24655	7890-3820	
S105	Rotary, 3 position, 1 section	7890-3830	24655	7890-3830	
S106	Toggle, DPDT	7910-1500	04009	83054-SA	5930-914-6723
S107	Rotary	6040-1955			
S501	Toggle, DPST	7910-1300	04009	83053-SA	5930-909-3510
MISCELLANEOUS					
F501	For 115-V operation:				
	0.2 A 3 AG Slo-Blo	5330-0600	71400	MDL, 0.2 A	
	For 230-V operation:				
	0.1 A 3 AG Slo-Blo	5330-0400	71400	MDL, 0.1 A	5920-356-2185
F502	For 115-V operation:				
	0.2 A 3 AG Slo-Blo	5330-0600	71400	MDL, 0.2 A	
	For 230-V operation:				
	0.1 A 3 AG Slo-Blo	5330-0400	71400	MDL, 0.1 A	5920-356-2185
P101	Lamp, 6 V, 20 mA ±10%	5600-1001	24655	5600-1001	6240-933-5816
P102	Lamp, 2 V, 60 mA	5600-0800	24454	#49 2 V, .06 A	
P103	Lamp, 6.3 V, 250 mA	5600-0800	24454	#49 2 V, .06 A	
M101	Meter, 50μA, 2%, 2kΩ ±10%	5730-1383	40931	Meds - 1383	
T101	Transformer	0746-4440	24655	0746-4440	
T102	Transformer	0745-4130	24655	0745-4130	
T501	Transformer	0345-4012	24655	0345-4012	

Figure 6-13. Over-all schematic diagram for the Type 1617 Capacitance Bridge.



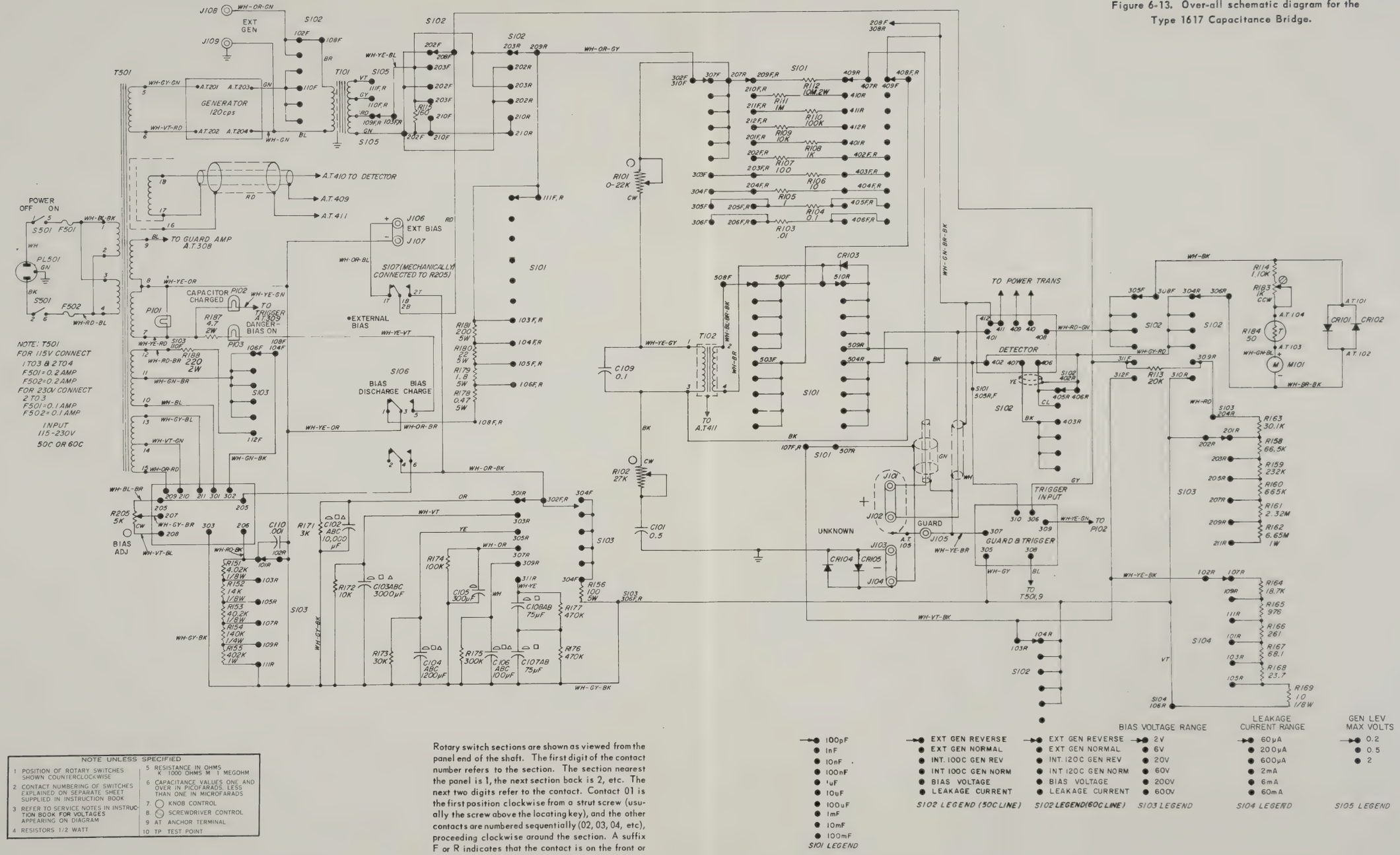
PARTS LIST for 100 and 500 series only

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
CAPACITORS					
C101	Standard, 0.5μF 1/4% 800 V	0236-4050	24655	0236-4050	
C102	Electrolytic, 5000x2500x2500 μF +100-10% 6 V	4450-5608	37942	TT, 5K/2.5K/2.5K μF	
C103	Electrolytic, 1500x750x750 μF +100-10% 25 V	4450-0700	90201	203828S10C10x2	5910-976-9415
C104	Electrolytic, 600x300x300 μF +100-10% 75 V	4450-5606	37942	FP20000022414005	
C105	Electrolytic, 300μF +100-10% 150 V	4450-5602	37942	20-22287991	5910-931-7039
C106	Electrolytic, 50x25x25μF +100-10% 450 V	4450-0800	56289	D28936	5910-970-1589
C107	Electrolytic, 50x25 μF +100-10% 450 V	4450-0800	56289	D28936	5910-970-1589
C108	Electrolytic, 50x25 μF +100-10% 450 V	4450-0800	56289	D28936	5910-970-1589
C109	Plastic, 0.1μF ±10% 100 V	4860-8250	84411	663uW, 0.1μF ±10%	
C110	Ceramic, 0.001μF ±10% 500 V	4405-2108	72982	801, 0.001μF ±10%	
DIODES					
CR101/2	Type 1N4140	6081-1014		1N4140	
CR103 thru CR105	Type 1N3253	6081-1001	79089	1N3253	5961-814-4251
JACKS					
Binding-post assemblies also require an 8080-0100 No. 6 washer, an 8040-1900 No. 6 lockwasher, and a 5810-2400 No. 6 nut for mounting.					
J101	Binding-post assembly	0938-4252	24655	0938-4252	
J102	Binding-post assembly	0938-4252	24655	0938-4252	
J103	Binding-post assembly	0938-3000	24655	0938-3000	
J104	Binding-post assembly	0938-3000	24655	0938-3000	
J105	Binding-post assembly	0938-3002	24655	0938-3002	
J106	Binding-post assembly	0938-3003	24655	0938-3003	
J107	Binding-post assembly	0938-3000	24655	0938-3000	
J108	Binding-post assembly	0938-3002	24655	0938-3002	
J109	Binding-post assembly	0938-3000	24655	0938-3000	
RESISTORS					
R101	Potentiometer, Wire-wound, 22kΩ	0433-4130	24655	0433-4130	
R102	Potentiometer, Wire-wound, 27kΩ	0977-4100	24655	0977-4100	
R103	Wire-wound, 0.01Ω ±0.25%	1617-1190	24655	1617-1190	
R104	Wire-wound, 0.1Ω ±0.25%	1617-1180	24655	1617-1180	
R105	Wire-wound, 1Ω ±0.1%	0500-0300	24655	0500-0300	
R106	Wire-wound, 10Ω ±0.05%	0602-3019	24655	0602-3019	
R107	Wire-wound, 100Ω ±0.025%	0510-3902	24655	0510-3902	
R108	Wire-wound, 1kΩ ±0.025%	0602-3040	24655	0602-3040	5905-501-7649
R109	Wire-wound, 10kΩ ±0.025%	0602-3052	24655	0602-3052	5905-797-3776
R110	Wire-wound, 100kΩ ±0.025%	0510-3600	24655	0510-3600	5905-963-7759
R111	Film, 1MΩ ±0.25% 1/2 W	6193-4100	75042	MEC, 1MΩ ±0.25%	
R112	Film, 10MΩ ±0.25% 2 W	6195-5100	75042	MEH, 10MΩ ±1%	
R113	Film, 20kΩ ±1% 1/2 W	6450-2200	75042	CEC-T0, 20kΩ ±1%	
R114	Film, 1.1kΩ ±1% 1/2 W	6450-1110	75042	CEC-T0, 1.1kΩ ±1%	
R115	Composition, 160Ω ±5% 1/2 W	6100-1165	01121	RC20GF161J	5905-256-0415
R151	Film, 4.02kΩ ±1% 1/8 W	6250-1402	75042	CEA, 4.02kΩ ±1%	5905-702-7231
R152	Film, 14kΩ ±1% 1/8 W	6250-2140	75042	CEA, 14kΩ ±1%	
R153	Film, 40.2kΩ ±1% 1/8 W	6250-2402	75042	CEA, 40.2kΩ	5905-801-8119
R154	Film, 140kΩ ±1% 1/4 W	6350-3140	75042	CEB, 140kΩ ±1%	
R155	Film, 402kΩ ±1% 1 W	6550-3402	75042	MEF, 402kΩ ±1%	5905-502-9148
R156	Wire-wound, 100Ω ±5% 5 W	6660-1105	80183	246E, 100Ω ±5%	
R158	Film, 66.5kΩ ±1% 1/2 W	6450-2665	75042	CEC, 66.5kΩ ±1%	5905-581-1252
R159	Film, 232kΩ ±1% 1/2 W	6450-3232	75042	CEC, 232kΩ ±1%	
R160	Film, 665kΩ ±1% 1/2 W	6450-3665	75042	CEC, 665kΩ ±1%	
R161	Film, 2.32MΩ ±1% 1/2 W	6450-4232	75042	CEC, 2.32MΩ ±1%	
R162	Film, 6.65MΩ ±1% 1 W	6550-4665	75042	MEF, 6.65MΩ ±1%	5905-800-2815
R163	Film, 30.1kΩ ±1% 1/2 W	6450-2301	75042	CEC, 30.1kΩ ±1%	5905-556-3783
R164	Film, 18.7kΩ ±1% 1/2 W	6450-2187	75042	CEC-T0, 18.7kΩ ±1%	
R165	Film, 976Ω ±1% 1/2 W	6450-0976	75042	CEC, 976Ω ±1%	
R166	Film, 261Ω ±1% 1/2 W	6450-0261	75042	CEC, 261Ω ±1%	
R167	Film, 68.1Ω ±1% 1/2 W	6450-0068	75042	CEC, 68.1Ω ±1%	
R168	Film, 23.7Ω ±1% 1/2 W	6450-0023	75042	CEC, 23.7Ω ±1%	
R169	Film, 10Ω ±1% 1/8 W	6250-0010	75042	CEA, 10Ω ±1%	5905-892-0062
R171	Composition, 3kΩ ±5% 1/2 W	6100-2305	00121	RC20GF302J	5905-279-1751
R172	Composition, 10kΩ ±5% 1/2 W	6100-3105	01121	RC20GF103J	5905-185-8510
R173	Composition, 30kΩ ±5% 1/2 W	6100-3305	01121	RC20GF303J	5905-192-3978
R174	Composition, 100kΩ ±5% 1/2 W	6100-4105	01121	RC20GF104J	5905-195-6761

PARTS LIST for 100 and 500 series only (cont)

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
RESISTORS (Cont)					
R175	Composition, 300kΩ ±5% 1/2 W	6100-4305	01121	RC20GF304J	5905-185-6859
R176	Composition, 470kΩ ±5% 1/2 W	6100-4475	01121	RC20GF474J	5905-279-2515
R177	Composition, 470kΩ ±5% 1/2 W	6100-4475	01121	RC20GF474J	5905-279-2515
R178	Wire-wound, 0.47Ω ±10% 5 W	6660-9047	75042	AS-5, 0.47Ω ±10%	
R179	Wire-wound, 1.8Ω ±5% 5 W	6660-9185	75042	AS-5, 1.8Ω ±5%	
R180	Wire-wound, 22Ω ±5% 5 W	6660-0225	80183	246E, 22Ω ±5%	5905-448-5687
R181	Wire-wound, 200Ω ±5% 5 W	6660-1205	80183	246E, 200Ω ±5%	
R183	Potentiometer, wire-wound, 1kΩ ±10%	6050-1300	12697	43, 1kΩ ±10%	
R184	Thermistor, 50Ω ±10%	6740-1900	02606	CB15L1	
R187	Wire-wound, 4.7Ω ±10% 2 W	6760-9479	75042	BWH, 220Ω ±10% 2 W	
R188	Wire-wound, 220Ω ±10% 2 W	6760-1229	75042	AS-10, 3kΩ ±5%	
SWITCHES					
S101	Rotary, 10 position, 5 section	7890-3790	24655	7890-3790	
S102	Rotary, 6 position, 4 section	7890-3800	24655	7890-3800	
S103	Rotary, 6 position, 3 section	7890-3810	24655	7890-3810	
S104	Rotary, 6 position, 1 section	7890-3820	24655	7890-3820	
S105	Rotary, 3 position, 1 section	7890-3830	24655	7890-3830	
S106	Toggle, DPDT	7910-1500	04009	83054-SA	5930-914-6723
S107	Rotary	6040-1955			
S501	Toggle, DPST	7910-1300	04009	83053-SA	5930-909-3510
MISCELLANEOUS					
F501	For 115-V operation: 0.2 A 3 AG Slo-Blo	5330-0600	71400	MDL, 0.2 A	
	For 230-V operation: 0.1 A 3 AG Slo-Blo	5330-0400	71400	MDL, 0.1 A	5920-356-2185
F502	For 115-V operation: 0.2 A 3 AG Slo-Blo	5330-0600	71400	MDL, 0.2 A	
	For 230-V operation: 0.1 A 3 AG Slo-Blo	5330-0400	71400	MDL, 0.1 A	5920-356-2185
P101	Lamp, 6 V, 20 mA ±10%	5600-1001	24655	5600-1001	6240-933-5816
P102	Lamp, 2 V, 60 mA	5600-0800	24454	#49 2 V, .06 A	
P103	Lamp, 6.3 V, 250 mA	5600-0800	24454	#49 2 V, .06 A	
M101	Meter, 50μA, 2%, 2kΩ ±10%	5730-1383	40931	Meds - 1383	
T101	Transformer	0746-4440	24655	0746-4440	
T102	Transformer	0745-4130	24655	0745-4130	
T501	Transformer	0345-4012	24655	0345-4012	

Figure 6-13. Over-all schematic diagram for the Type 1617 Capacitance Bridge.


NOTE: T501
FOR 115V CONNECT
1 T03 & 2 T04
F501 = 0.2 AMP
F502 = 0.2 AMP
FOR 230V CONNECT
2 T03
F501 = 0.1 AMP
F502 = 0.1 AMP
INPUT
115-230V
50C OR 60C
NOTE UNLESS SPECIFIED
1 POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE
2 CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK
3 REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM
4 RESISTORS 1/2 WATT
5 RESISTANCE IN OHMS K 1000 OHMS M 1 MEGOHM
6 CAPACITANCE VALUES ONE AND OVER IN PICOFARADS, LESS THAN ONE IN MICROFARADS
7. KNOB CONTROL
8. SCREWDRIVER CONTROL
9 AT ANCHOR TERMINAL
10 TP TEST POINT
Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.
S101 LEGEND
100pF
1nF
10nF
100nF
1uF
10uF
100uF
1mF
10mF
100mF
S102 LEGEND (50C LINE)
EXT GEN REVERSE
EXT GEN NORMAL
INT. 100C GEN REV
INT 100C GEN NORM
BIAS VOLTAGE
LEAKAGE CURRENT
S102 LEGEND(60C LINE)
EXT GEN REVERSE
EXT GEN NORMAL
INT. 120C GEN REV
INT 120C GEN NORM
BIAS VOLTAGE
LEAKAGE CURRENT
S103 LEGEND
BIAS VOLTAGE RANGE
2V
6V
20V
60V
200V
600V
S104 LEGEND
LEAKAGE CURRENT RANGE
60µA
200µA
600µA
2mA
6mA
60mA
S105 LEGEND
GEN LEV MAX VOLTS
0.2
0.5
2

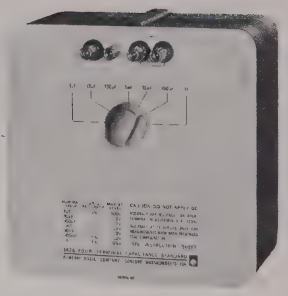
APPENDIX

FOUR-TERMINAL CAPACITANCE STANDARD

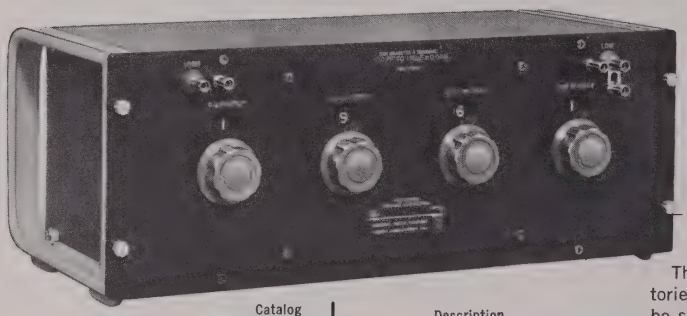
Type 1426

Capacitance	1 μF	10 μF	100 μF	1 mF	10 mF	100 mF	1 F

The 1426 capacitance standard is of great value in calibrating four-terminal, high-capacitance bridges like the GR 1617. With calibration, the 1426 can be used as a two-terminal standard at 120 Hz and at settings up to 1 mF.



Catalog Number	Description
1426-9700	**1426 Four-Terminal Capacitance Standard**



PRECISION DECADE CAPACITOR

Type 1423-A

This capacitor is a versatile tool for calibration laboratories and production-line testing. With it a bridge can be standardized to an accuracy exceeded only by that of the highest quality, individually certified laboratory standards

Any value of capacitance from 100 pF to 1.111 μF, in steps of 100 pF, can be set on the four decades and will be known to an accuracy of 0.05%.

Catalog Number	Description
	Precision Decade Capacitor
1423-9801	**1423-A,** Bench Model
1423-9811	**1423-A,** Rack Model

STANDARD CAPACITOR

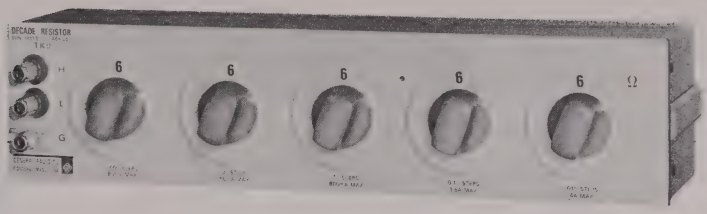
Type 1409

Catalog Number	Type	Nominal Capacitance μF	Frequency Limit for Max Volts
1409-9706	**1409-F**	0.001	4.7 MHz
1409-9707	**1409-G**	0.002	2.7 MHz
1409-9711	**1409-K**	0.005	1.3 MHz
1409-9712	**1409-L**	0.01	750 kHz
1409-9713	**1409-M**	0.02	430 kHz
1409-9718	**1409-R**	0.05	210 kHz
1409-9720	**1409-T**	0.1	120 kHz
1409-9721	**1409-U**	0.2	70 kHz
1409-9724	**1409-X**	0.5	35 kHz
1409-9725	**1409-Y**	1.0	17 kHz

The 1409 Standard Capacitors are fixed mica capacitors of very high stability for use as two- or three-terminal reference or working standards in the laboratory.

DECADE RESISTOR

Type 1433



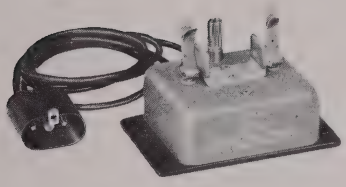
- ±0.02% accuracy
- good frequency characteristics
- low temperature coefficient
- excellent stability
- low zero resistance

The 1433 Decade Resistors are primarily intended for precision measurement applications where their excellent accuracy, stability, and low zero resistance are important. They are convenient resistance standards for checking the accuracy of resistance-measuring devices and are used as components in dc and audio-frequency impedance bridges.

Catalog Number				Ohms per Step	No. of Dials
Bench	Rack	Type	Total Ohms		
1433-9700	1433-9701	1433-U	111.1	0.01	4
1433-9702	1433-9703	1433-K	1111	0.1	4
1433-9704	1433-9705	1433-J	11,110	1	4
1433-9706	1433-9707	1433-L	111,100	10	4
1433-9708	1433-9709	1433-Q	1,111,000	100	4
1433-9710	1433-9711	1433-T	1111.1	0.01	5
1433-9712	1433-9713	1433-N	11,111	0.1	5
1433-9714	1433-9715	1433-M	111,110	1	5
1433-9716	1433-9717	1433-P	1,111,100	10	5
1433-9718	1433-9719	1433-Y	11,111,000	100	5
1433-9720	1433-9721	1433-W	11,111.1	0.01	6
1433-9722	1433-9723	1433-X	111,111	0.1	6
1433-9724	1433-9725	1433-B	1,111,110	1	6
1433-9726	1433-9728	1433-Z	11,111,100	10	6
1433-9729	1433-9730	1433-F	111,111.1	0.01	7
1433-9731	1433-9732	1433-G	1,111,111	0.1	7
1433-9733	1433-9734	1433-H	11,111,110	1	7

TEST JIG

Type 1650-P1



This test-jig adaptor is used to connect components quickly to a pair of terminals and can be placed on the bench directly in front of the operator.

The test jig makes a three-terminal connection to the bridge, so that the residual zero capacitance is negligible.

The lead resistance (0.08 ohm total) has effect only when very low impedances are measured, and the lead capacitance affects only the measurement of the Q of inductors, introducing a small error in D $\left(\text{or } \frac{1}{Q}\right)$ of less than 0.007.

Catalog Number	Description
1650-9601	**1650-P1 Test Jig**

PATCH-CORD ACCESSORIES

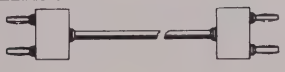
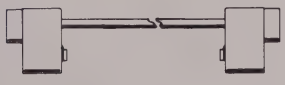
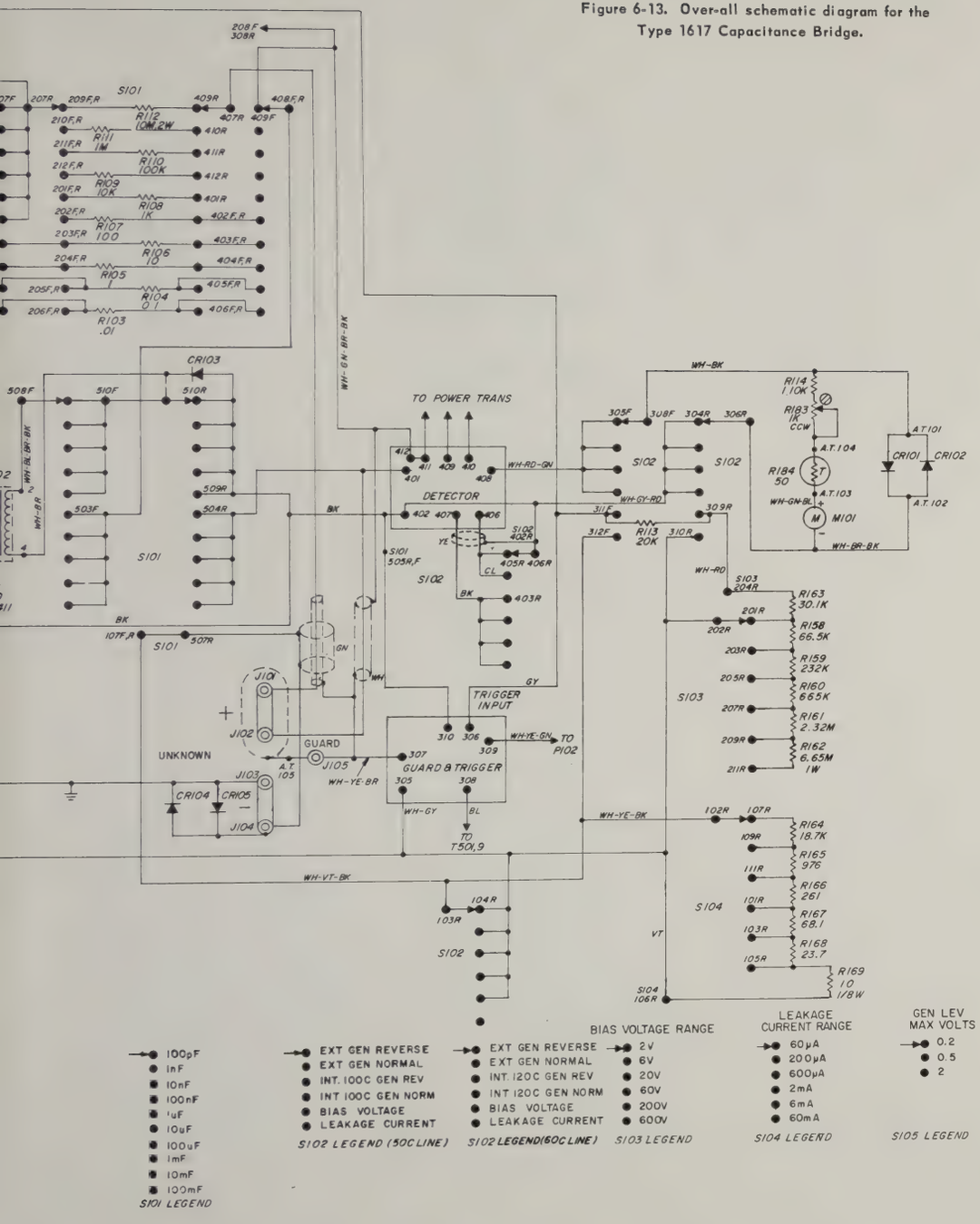
	Type	*Description*	*Catalog Number*
	274-NQ	Double-plug patch cord, in-line cord, 36" long	0274-9860
	274-NQM	Double-plug patch cord, in-line cord, 24" long	0274-9896
	274-NQS	Double-plug patch cord, in-line cord, 12" long	0274-9861
	274-NP	Double-plug patch cord, right-angle cord, 36" long	0274-9880
	274-NPM	Double-plug patch cord, right-angle cord, 24" long	0274-9892
	274-NPS	Double-plug patch cord, right-angle cord, 12" long	0274-9852
	274-NL	Shielded double-plug patch cord, 36" long	0274-9883
	274-NLM	Shielded double-plug patch cord, 24" long	0274-9882
	274-NLS	Shielded double-plug patch cord, 12" long	0274-9862
	274-LLB	Single-plug patch cord, black, 36" long	0274-9468
	274-LLR	Single-plug patch cord, red, 36" long	0274-9492
	274-LMB	Single-plug patch cord, black, 24" long	0274-9847
	274-LMR	Single-plug patch cord, red, 24" long	0274-9848
	274-LSB	Single-plug patch cord, black, 12" long	0274-9849
	274-LSR	Single-plug patch cord, red, 12" long	0274-9850

Figure 6-13. Over-all schematic diagram for the Type 1617 Capacitance Bridge.



APPENDIX

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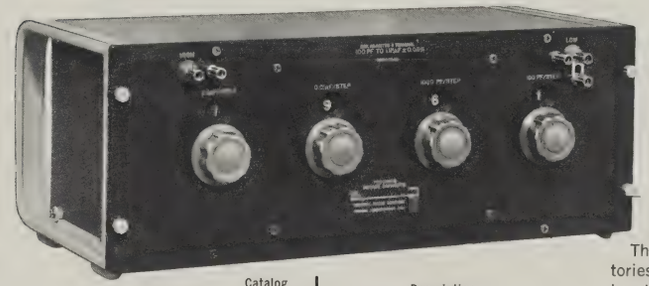
Catalog Number	Description
1426-9700	**1426 Four-Terminal Capacitance Standard**



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Type 1409

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1409-9720	**1409-T**	0.1	120 kHz
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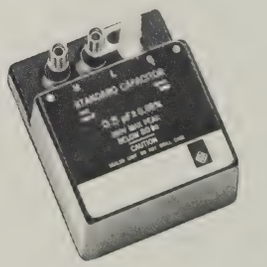
1409-9724	**1409-X**	0.5	35 kHz
1409-9725	**1409-Y**	1.0	17 kHz



The 1409 Standard Capacitors are fixed mica capacitors of very high stability for use as two- or three-terminal reference or working standards in the laboratory.

MECHANICAL REPLACEMENT PARTS LIST

Ref. Desig.	Description	GR Part No.	FMC	Mfg. Part No.	Fed. Stock No.
MECHANICAL REPLACEMENT PARTS					
	Handle and Bracket Assembly	1617-2010	24655	1617-2010	
	Dial Asm. (Leakage Current)	1617-2140	24655	1617-2140	
	Knob	5520-5320	24655	5520-5320	
	Dial Asm. (Multiplier)	1617-2150	24655	1617-2150	
	Knob	5500-5420	24655	5500-5420	
	Dial Asm. (50-Hz Operation)	1617-2170	24655	1617-2170	
	Knob Function Switch	5500-5420	24655	5500-5420	
	Dial Asm. (60-Hz Operation)	1617-2190	24655	1617-2190	
	Knob Function Switch	5500-5420	24655	5500-5420	
	Dial Asm. (Bias Voltage Range)	1617-2130	24655	1617-2130	
	Knob	5520-5320	24655	5520-5320	
	Knob and Dial Asm. (Main Balance Control for Dissipation Factor)				
	Dial Asm.	1617-1250	24655	1617-1250	
	Knob 50-Hz Operation	5520-5520	24655	5520-5520	
	Knob and Dial Asm. (Main Balance Control for Dissipation Factor)				
	Dial Asm.	1617-1260	24655	1617-1260	
	Knob 60-Hz Operation	5520-5520	24655	5520-5520	
	Knob and Dial Asm. (Main Balance Control for Capacitance)	1617-3080	24655	1617-3080	
	Dial Asm.	1617-1270	24655	1617-1270	
	Knob	5520-5520	24655	5520-5520	
	Knob, Vernier	5500-5420	24655	5500-5420	
	Knob, Vernier	5500-5420	24655	5500-5420	
	Knob, Gen. Level Max. Volts	5520-5321	24655	5520-5321	
	Knob, Detector Sensitivity	5520-5321	24655	5520-5321	
	Knob, Bias Adjustment	5520-5321	24655	5520-5321	
	Handle (For Orthonull Lever)	1650-6010	24655	1650-6010	
	Indicator for Main Balance Control Dial	5460-1301	24655	5460-1301	6625-043-2124
	Pilot Light Cap	5620-0800	72619	95-935 Cap (Unfluted)	
	Etched Cir Asm. Detector 60-Hz Oper	1617-2700	24655	1617-2700	
	Etched Cir Asm. Detector, 50-Hz Oper	1617-2770	24655	1617-2770	
	Etched Cir Asm. Guard Amplifier and Trigger	1617-2730	24655	1617-2730	
	Etched Cir Asm. High-Voltage Supply and Generator 60-Hz Operation	1617-2720	24655	1617-2720	
	Etched Cir Asm. High-Voltage Supply and Generator 50-Hz Operation	1617-2780	24655	1617-2780	

FEDERAL MANUFACTURERS CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) as supplemented through June, 1967.

Code	Manufacturers Name and Address
00192	Jones Mfg. Co., Chicago, Illinois
00194	Walsco Electronics Corp., Los Angeles, Calif.
00656	Aerovox Corp., New Bedford, Mass.
01009	Alden Products Co., Brockton, Mass.
01121	Allen-Bradley, Co., Milwaukee, Wisc.
01295	Texas Instruments, Inc., Dallas, Texas
02114	Ferroxcube Corp. of America, Saugerties, N. Y. 12477
02606	Fenwal Lab. Inc., Morton Grove, Ill.
02660	Amphenol Electronics Corp., Broadview, Ill.
02768	Fastex Division of Ill. Tool Works, Des Plaines, Ill. 60016
03508	G. E. Semiconductor Products Dept., Syracuse, N. Y. 13201
03636	Grayburne, Yonkers, N. Y. 10701
03888	Pyrofilm Resistor Co., Cedar Knolls, N. J.
03911	Clairex Corp., New York, N. Y. 10001
04009	Arrow, Hart and Hegeman Electric Co., Hartford, Conn. 06106
04713	Motorola Semi-Conduct Product, Phoenix, Ariz. 85008
05170	Engineered Electronics Co., Inc., Santa Ana, Calif. 92702
05624	Barber-Colman Co., Rockford, Ill. 61101
05820	Wakefield Eng., Inc., Wakefield, Mass. 01880
07127	Eagle Signal Div. of E. W. Bliss Co., Baraboo, Wisc.
07261	Avnet Corp., Culver City, Calif. 90230
07263	Fairchild Camera and Instrument Corp., Mountain View, Calif.
07387	Birtcher Corp., No. Los Angeles, Calif.
07595	American Semiconductor Corp., Arlington Heights, Ill. 60004
07828	Bodine Corp., Bridgeport, Conn. 06605
07829	Bodine Electric Co., Chicago, Ill. 60618
07910	Continental Device Corp., Hawthorne, Calif.
07983	State Labs Inc., N. Y., N. Y. 10003
07999	Amphenol Corp., Borg Inst. Div., Delavan, Wisc. 53115
08730	Vemaline Prod. Co., Franklin Lakes, N. J.
09213	General Electric Semiconductor, Buffalo, N. Y.
09408	Star-Tronics Inc., Georgetown, Mass. 01830
09823	Burgess Battery Co., Freeport, Ill.
09922	Burndy Corp., Norwalk, Conn. 06852
11236	C,P,S, of Berne, Inc., Berne, Ind. 46711
11599	Chandler Evans Corp., W. Hartford, Conn.
12498	Teledyn Inc., Crystalonics Div., Cambridge, Mass. 02140
12672	RCA Commercial Receiving Tube and Semi-conductor Div., Woodridge, N.J.
12697	Clarostat Mfg. Co. Inc., Dover, N. H. 03820
12954	Dickson Electronics Corp., Scottsdale, Ariz.
13327	Solitrone Devices, Tappan, N. Y. 10983
14433	ITT Semiconductors, W. Palm Beach, Florida
14655	Cornell Dubilier Electric Co., Newark N. J.
14674	Corning Glass Works, Corning, N. Y.
14936	General Instrument Corp., Hicksville, N. Y.
15238	ITT, Semiconductor Div. of Int. T. and T, Lawrence, Mass.
15605	Cutler-Hammer Inc., Milwaukee, Wisc. 53233
16037	Spruce Pine Mica Co., Spruce Pine, N. C.
19644	LRC Electronics, Horseheads, New York
19701	Electra Mfg. Co., Independence, Kansas 67301
21335	Fafnir Bearing Co., New Briton, Conn.
24446	G. E. Schenectady, N. Y. 12305
24454	G. E., Electronic Comp., Syracuse, N. Y.
24455	G. E. (Lamp Div), Nela Park, Cleveland, Ohio
24655	General Radio Co., W. Concord, Mass 01781
26806	American Zettler Inc., Costa Mesa, Calif.
28520	Hayman Mfg. Co., Kenilworth, N. J.
28959	Hoffman Electronics Corp., El Monte, Calif.
30874	International Business Machines, Armonk, N.Y.
32001	Jensen Mfg. Co., Chicago, Ill. 60638
35929	Constanta Co. of Canada Limited, Montreal 19, Quebec
37942	P. R. Mallory and Co. Inc., Indianapolis, Ind.
38443	Marlin-Rockwell Corp., Jamestown, N. Y.
40931	Honeywell Inc., Minneapolis, Minn. 55408
42190	Muter Co., Chicago, Ill. 60638
42498	National Co, Inc., Melrose, Mass. 02176
43991	Norma-Hoffman Bearings Corp., Stanford, Conn. 06904
49671	RCA, New York, N. Y.
49956	Raytheon Mfg. Co., Waltham, Mass. 02154
53021	Sangamo Electric Co., Springfield, Ill. 62705
54294	Shallcross Mfg. Co., Selma, N. C.
54715	Shure Brothers, Inc., Evanston, Ill.
56289	Sprague Electric Co., N. Adams, Mass.
59730	Thomas and Betts Co., Elizabeth, N. J. 07207
59875	TRW Inc. (Accessories Div), Cleveland, Ohio
60399	Torrington Mfg. Co., Torrington, Conn.
61637	Union Carbide Corp., New York, N. Y. 10017
61864	United-Carr Fastener Corp., Boston, Mass.
63060	Victoreen Instrument Co., Inc., Cleveland, Ohio
63743	Ward Leonard Electric Co., Mt. Vernon, N. Y.
65083	Westinghouse (Lamp Div), Bloomfield, N. J.
65092	Weston Instruments, Weston-Newark, Newark, N. J
70485	Atlantic-India Rubber Works, Inc., Chicago, Ill. 60607
70563	Amperite Co., Union City, N. J. 07087
70903	Belden Mfg. Co., Chicago, Ill. 60644
71126	Bronson, Homer D., Co., Beacon Falls, Conn.
71294	Canfield, H. O. Co., Clifton Forge, Va. 24422
71400	Bussman Mfg. Div. of McGraw Edison Co., St. Louis, Mo.
71590	Centralab, Inc., Milwaukee, Wisc. 53212
71666	Continental Carbon Co., Inc., New York, N. Y.
71707	Coto Coil Co. Inc., Providence, R. I.
71744	Chicago Miniature Lamp Works, Chicago, Ill.
71785	Cinch Mfg. Co. and Howard B. Jones Div., Chicago, Ill. 60624
71823	Darnell Corp., Ltd., Downey, Calif. 90241
72136	Electro Motive Mfg. Co., Willmington, Conn.
72259	Nytronics Inc., Berkeley Heights, N. J. 07922
72619	Dialight Co., Brooklyn, N. Y. 11237
72699	General Instrument Corp., Capacitor Div., Newark, N. J. 07104
72765	Drake Mfg. Co., Chicago, Ill. 60656
72825	Hugh H. Eby, Inc., Philadelphia, Penn. 19144
72962	Elastic Stop Nut Corp., Union, N. J. 07083
72982	Erie Technological Products Inc., Erie, Penn.
73138	Beckman, Inc., Fullerton, Calif. 92634
73445	Amperex Electronics Co., Hicksville, N. Y.
73559	Carling Electric Co., W. Hartford, Conn.
73690	Elco Resistor Co., New York, N. Y.
73899	J. F. D. Electronics Corp., Brooklyn, N. Y.
74193	Heinemann Electric Co., Trenton, N. J.
74861	Industrial Condenser Corp., Chicago, Ill.
74970	E. F. Johnson Co., Waseca, Minn. 56093
75042	IRC Inc., Philadelphia, Penn. 19108
75382	Kulka Electric Corp., Mt. Vernon, N. Y.
75491	Lafayette Industrial Electronics, Jamaica, N.Y.
75608	Linden and Co., Providence, R. I.
75915	Littelfuse, Inc., Des Plaines, Ill. 60016
76005	Lord Mfg. Co., Erie, Penn. 16512
76149	Malloy Electric Corp., Detroit, Mich. 48204
76487	James Millen Mfg. Co., Malden,Mass. 02148
76545	Mueller Electric Co., Cleveland, Ohio 44114
76684	National Tube Co., Pittsburg, Penn.
76854	Oak Mfg. Co., Crystal Lake, Ill.
77147	Patton MacGuyer Co., Providence, R. I.
77166	Pass-Seymour, Syracuse, N. Y.
77263	Pierce Roberts Rubber Co., Trenton, N. J.
77339	Positive Lockwasher Co., Newark , N. J.
77542	Ray-O-Vac Co., Madison, Wisc.
77630	TRW, Electronic Component Div., Camden, N. J. 08103
77638	General Instruments Corp., Brooklyn, N. Y.
78189	Shakeproof Div. of Ill. Tool Works, Elgin, Ill. 60120
78277	Sigma Instruments Inc., S. Braintree, Mass.
78488	Stackpole Carbon Co., St. Marys, Penn.
78553	Tinnerman Products, Inc., Cleveland, Ohio
79089	RCA, Commercial Receiving Tube and Semi-conductor Div., Harrison, N. J.
79725	Wiremold Co., Hartford, Conn. 06110
79963	Zierick Mfg. Co., New Rochelle, N. Y.
80030	Prestole Fastener Div. Bishop and Babcock Corp., Toledo, Ohio
80048	Vickers Inc. Electric Prod. Div., St. Louis, Mo.
80131	Electronic Industries Assoc., Washington, D.C.
80183	Sprague Products Co., N. Adams, Mass.
80211	Motorola Inc., Franklin Park, Ill. 60131
80258	Standard Oil Co., Lafeyette, Ind.
80294	Bourns Inc., Riverside, Calif. 92506
83033	Meissner Mfg., Div. of Maguire Industries, Inc. Mount Carmel, Illinois
80431	Air Filter Corp., Milwaukee, Wisc. 53218
80583	Hammarlund Co. Inc., New York, N. Y.
80740	Beckman Instruments, Inc., Fullerton, Calif.
81073	Grayhill Inc., LaGrange, Ill. 60525
81143	Isolantite Mfg. Corp., Stirling, N. J. 07980
81349	Military Specifications
81350	Joint Army-Navy Specifications
81751	Columbus Electronics Corp., Yonkers, N. Y.
81831	Filton Co., Flushing, L. I., N. Y
81860	Barry Controls Div. of Barry Wright Corp., Watertown, Mass.
82219	Sylvania Electric Products, Inc., (Electronic Tube Div.), Emporium, Penn.
82273	Indiana Pattern and Model Works, LaPort, Ind.
82389	Switchcraft Inc., Chicago, Ill. 60630
82647	Metals and Controls Inc., Attleboro, Mass.
82807	Milwaukee Resistor Co., Milwaukee, Wisc.
83058	Carr Fastener Co., Cambridge, Mass.
83186	Victory Engineering Corp (IVECO), Springfield, N. J. 07081
83361	Bearing Specialty Co., San Francisco, Calif.
83587	Solar Electric Corp., Warren, Penn.
83740	Union Carbide Corp., New York, N. Y. 10017
84411	TRW Capacitor Div., Ogallala, Nebr.
84835	Lehigh Metal Products Corp., Cambridge, Mass. 02140
84971	TA Mfg. Corp., Los Angeles, Calif.
86577	Precision Metal Products of Malden Inc., Stoneham, Mass. 02180
86684	RCA (Electrical Component and Devices) Harrison. N. J.
86800	Continental Electronics Corp, Brooklyn, N.Y. 11222
88140	Cutler-Hammer Inc., Lincoln, Ill.
88219	Gould Nat. Batteries Inc., Trenton, N. J.
88419	Cornell Dubilier Electric Corp., Fuquay-Varina, N. C.
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89482	Holtzer Cabot Corp., Boston, Mass.
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91032	Continental Wire Corp., York, Penn. 17405
91146	ITT Cannon Electric Inc., Salem, Mass.
91293	Johanson Mfg. Co., Boonton, N. J. 07005
91598	Chandler Co., Wethersfield, Conn. 06109
91637	Dale Electronics Inc., Columbus, Nebr.
91662	Elco Corp., Willow Grove, Penn.
91719	General Instruments, Inc., Dallas, Texas
91929	Honeywell Inc., Freeport, Ill.
92519	Electra Insulation Corp., Woodside, Long Island, N. Y.
92678	Edgerton, Germeshausen and Grier, Boston, Mass.
93332	Sylvania Electric Products, Inc., Woburn, Mass.
93916	Cramer Products Co., New York, N. Y. 10013
94144	Raytheon Co. Components Div., Quincy, Mass.
94154	Tung Sol Electric Inc., Newark, N. J.
95076	Garde Mfg. Co., Cumberland, R. I.
95146	Alco Electronics Mfg. Co., Lawrence, Mass.
95238	Continental Connector Corp., Woodside, N. Y.
95275	Vitramon, Inc., Bridgeport, Conn.
95354	Methode Mfg. Co., Chicago, Ill.
95412	General Electric Co., Schenectady, N. Y.
95794	Ansconda American Brass Co., Torrington, Conn.
96095	Hi-Q Div. of Aerovox Corp., Orlean, N. Y.
96214	Texas Instruments Inc., Dallas, Texas 75209
96256	Thordarson-Meissner Div. of McGuire, Mt. Carmel, Ill.
96341	Microwave Associates Inc., Burlington, Mass.
96791	Amphenoe Corp, Jonesville, Wisc. 53545
96906	Military Standards
97966	CBS Electronics Div. of Columbia Broadcasting Systems, Danvers, Mass.
98291	Sealectro Corp., Mamaroneck, N. Y. 10544
98821	North Hills Electronics Inc., Glen Cove, N. Y.
99180	Transitron Electronics Corp., Melrose, Mass.
99378	Atlee Corp., Winchester, Mass. 01890
99800	Delevan Electronics Corp., E. Aurora, N. Y.

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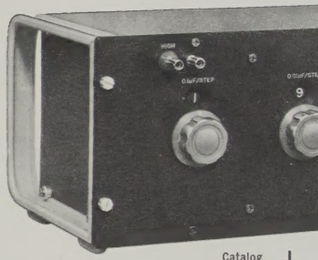
FOUR-TERMI CAPACITANC STANDARD

Type 1426

Capacitance	1 μF	10 μF	100 μF	1 mF

The 1426 capacitance standard is calibrating four-terminal, high-capacit the GR 1617. With calibration, the 14 a two-terminal standard at 120 Hz and 1 mF.



Catalog Number	
1423-9801	
1423-9811	

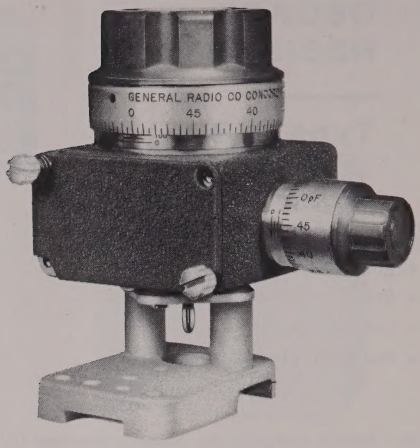
STANDAR CAPACIT

Type 140

Catalog Number	Type	Nomin Capac tanc μF
1409-9706	1409-F	0.00
1409-9707	1409-G	0.00
1409-9711	1409-K	0.00
1409-9712	1409-L	0.01
1409-9713	1409-M	0.02
1409-9718	1409-R	0.05
1409-9720	1409-T	0.1
1409-9721	1409-U	0.2
1409-9724	1409-X	0.5
1409-9725	1409-Y	-1.0

DIELECTRIC SAMPLE HOLDER

Type 1690-A



- micrometer-electrode-type for dielectric disks
- wide frequency range; fits many instruments
- calibration corrects for fringing and strays
- stable mounting, complete shielding

Catalog Number	Description
1690-9701	**1690-A Dielectric Sample Holder**
1690-9602	**1690-P2 Adaptor Assembly (for connecting to GR874 coaxial equipment)**

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